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METEOROLOGY AND WAR-FLYING, SOME PRACTICAL SUGGESTIONS*

ROBERT DE C. WARD

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INTRODUCTION.—A Presidential Address before the Association of American Geographers in war time must inevitably concern itself with war. Never, in the long history of man's struggle with man, has there been such emphasis upon the importance of geographic controls over military operations. Never has the part played by topography, by soils, by the surface covering of the earth, by the atmosphere, been so obvious. Never has a knowledge of geographic conditions had such immediate practical bearing upon the conduct of war. Never have geographers had such an opportunity to help their country successfully to wage war as they now have, when they place their scientific knowledge at the service of those who can make the most effective use of it.

Every member of this Association has, in some way, done his share in helping the country in this crisis. To some of us the call to service has meant active military duty. To others, it has meant the abandonment of our own cherished plans, and the taking up of other work which the country needs to have done, and by us. To others, it has meant the orderly performance of our daily task, of educating our youth so that they may be better fitted for their duties as intelligent

* A Presidential Address prepared for presentation before the Association of American Geographers.

citizens; or of carrying on some research whose results will be of practical benefit to the country. To every one of us the call to service has come. Every one of us has heeded that call.

In an emergency like this, your President is convinced that you will expect no formal, conventional Presidential Address. You will feel, with him, that the subject of this Address should have immediate bearing upon some geographic topic connected with our participation in the war. And your desire, he is satisfied, will be that this Address shall, if possible, be of help to others who may be called upon to deal with the problems and conditions which are here presented.

To your President the call to service has brought the responsibility of giving instruction in Meteorology at the United States Army School of Military Aeronautics, established in May, 1917, at the Massachusetts Institute of Technology. Preparation for this work involved an immediate visit to the Cadet School of the Royal Flying Corps in Toronto. From officers of the Royal Flying Corps in Canada; from Dr. J. Patterson, in charge of meteorological instruction at the Cadet School in Toronto; from official publications of the Meteorological Office and of the Royal Flying Corps, and from numerous books and articles on aviation and aeronautics, many helpful suggestions have been received. Such of this information as was "confidential" is, for obvious reasons, not here included. The experience of the men who have done actual flying must be drawn upon as an indispensable help in planning any such instruction. The purpose here is to outline, briefly, some of the most essential meteorological facts which those who are to engage in flying should know. This is no time to give a history of the exploration of the free air, or a summary of the knowledge obtained through such exploration. In avoiding these topics, this Address departs from the usual conventional lines laid down by precedent for such a paper.

The military aviator must have his meteorological facts presented in the simplest, clearest and most practical possible way. Meteorology is but a small part of the varied and highly complex information which is necessary in his exacting, absorbing and dangerous occupation. Theories should be omitted altogether, and explanations, except of certain essential facts, are unnecessary. There are important meteorological problems whose solution awaits the collection and study of further facts from the free air. These facts may easily be secured by our aviators.[1] A skilful teacher will know how to suggest some

[1] The importance of such observations in meteorology is well illustrated in a recent paper by C. K. M. Douglas, Lieut., R. F. C., "Weather Observation from an Aeroplane," *Journ. Scot. Met. Soc.*, 3d ser., Vol. 17, No. 33, 1916, pp. 65-73. These observations were made in the spring and summer of 1916, when the author was flying almost daily among the clouds up to heights of 8,000 to 10,000 feet.

of the most easily observable conditions concerning which meteorologists very much desire further information. Thus the interests of our flyers will be aroused, and those who have the spirit of discovery will be able to make valuable contributions to our present knowledge of conditions in the free air. The keynote of the meteorologist's contribution toward the training for flying in war is the desire to make aviation a more effective means of waging war, and to save the lives of some of our flyers. Mention of the dangers resulting from atmospheric conditions should, so far as possible, be avoided. The atmosphere is not infrequently an opponent of sufficient strength to call forth all a man has of courage, of sound judgment, of endurance, but even a relatively slight knowledge of meteorology may, in many cases, save the more serious consequences which might arise from unfavorable weather.

There is no need of emphasizing the importance of a knowledge of meteorology on the part of those whose business it is to sail through the ocean of air.[2] This ocean has its tides, its currents, its waves. It is beginning to be charted, but only just beginning.[3] A seaman navigates his vessel in all sorts of weather, but skill in local weather forecasting, and a practical knowledge of the laws of storms, are invalu-

[2] General references: Great Britain. Royal Flying Corps. Training manual.

Shaw, Sir Napier. "The weather map." Meteorological Office, London, 1917. 3d issue. (M. O. no. 2251.)

In addition to these sources of information, and other references given later, the following publications may prove useful:

Linke, Franz. "Aeronautische Meteorologie," Pt. I and II. Frankfurt a/M., 1911. 133 and 126 p. 8°. (Deals chiefly with balloons and is somewhat out of date, but still useful.)

Humphreys, W. J. "Physics of the Atmosphere." Jour. Franklin Instit., March, 1913. Especially pp. 229-241.

McAdie, Alex. G. "Principles of Aerography." Chicago, 1917. 8°. (The most recent book on the subject; summarizes the latest advances in meteorology; lays special emphasis on modern methods of dealing with the problems of the atmosphere, and on practical application of the available knowledge.)

Idem. "Aviation and aerography." Aviat. and aeronaut. engin., Aug. 15, 1916, 1:8-11; also in Sci. amer. suppl., June 2, 1917, No. 2161, pp. 341-342.

Idem. "Aerography: the science of the structure of the atmosphere." Geogr. rev., New York, April, 1916, 1:266-273.

Rotch, A. Lawrence. "Conquest of the air." New York, 1909. 8°.

Idem. "Sounding the ocean of air." 1900. 174 p. sm. 8°.

[3] Rotch, A. Lawrence, & Palmer, Andrew H. "Charts of the atmosphere for aeronauts and aviators." New York, 1911.

[This is a pioneer publication on its subject. It presents, in a practical form, some of the results obtained at Blue Hill Observatory, Mass., during 20 years of observation. The charts are "the first of their kind adapted to the use of airmen." They relate chiefly to Blue Hill, but apply also to larger portions of the United States. The final chart shows the best aerial routes across the North Atlantic Ocean in summer.]

able in making possible a speedier, safer, and more successful voyage. Similarly, the navigator of the air, though war service often involves flying under atmospheric conditions far from favorable, inevitably finds, sooner or later, that the more he knows about the air which he is navigating, the better equipped he is as a fighter, as a photographer, or on reconnaissance work. At critical times, meteorological knowledge has time and again proved its practical value to those who navigate the air. Meteorologists are waiting to put all that they know at the service of the men who fly. And the men who fly will, in their turn, advance meteorological science by means of the facts which their own practical experience in the air will impress upon their minds. He who knows most about practical meteorology is the best equipped for service in the air. He is, therefore, the most likely, other things being equal, to do his country the greatest service.

The aviator who is sent to a foreign war zone may wisely, if time allows, inform himself regarding the climate of the region in which he is to fly. It is a practical help to know about the prevailing winds, the number of stormy days, the distribution and amount of precipitation, the occurrence of gales, the general character of the weather, and the like. Such data are easily obtainable from the usual climatic summaries.[4] A convenient recent summary of French data is printed in the *Monthly Weather Review,* October, 1917, pp 487-496, and reprinted in the November or December, 1917, issues of the monthly "Climatological data" issued at section centers.

Climate is the average, and is made up of the individual, day-by-day atmospheric conditions which we call *weather*. A climatic summary for any given month, or season, shows the *average* or *normal* conditions. It by no means necessarily shows what any particular month or season is to be. There is no way, as yet, of knowing that in advance. Obviously, some knowledge of the weather which he is to experience to-day and to-morrow is of immediate and essential importance to the aviator. He is helped by knowing something of the general climatic conditions of his field of operations. But he wants, much

[4] The standard book on climate is J. von Hann: Handbuch der Klimatologie. 3d ed., Stuttgart, 1908-1911. 3 v. 8°.

On the western front the winds are prevailingly from the western quarter. Hence the German machines have an advantage in case of engine trouble. An Allied airplane will be likely to have "its gliding path so shortened that the aviator will mostly have to land in 'No Man's Land' if he does not come down within the enemy lines." F. W. Lanchester, the *London Times* correspondent on the western front, reports that "fighting nearly always drifts over the enemy's territory, and that the Germans habitually endeavor to draw our men farther over their own ground, where even a small mishap may prevent them, against the adverse winds, from regaining their own lines."

more, to know what weather to expect within the next few hours. In other words, he wants to know "not what *may* be but what *will* be."[5] He needs regular daily weather forecasts. And these require an organized system of meteorological observations, made by trained observers, collected by telegraph, and charted. With such an organized military meteorological field service the aviator is not himself directly concerned. The forecasts are supplied to him. He can, however, help himself a great deal if he has a good "working" knowledge of daily weather maps;[6] if he knows something of the relations and movements of weather types, and is sufficiently familiar with weather prognostics to be able to make his own rough-and-ready forecasts in case he can not receive the official forecast, or wishes to interpolate his own prediction at a time when no regular forecast is issued.

Details regarding the field weather service of the Allies are confidential, but information which has been given to the public shows that the meteorological organization is widespread and effective. So far as Great Britain is concerned, we know that a separate unit of the Royal Engineers has been created for meteorological service in the field. The service in France has been under the command of Maj. Ernest Gold, and that in the eastern Mediterranean under Capt. E. M. Wedderburn. With the latter is, or was, Lieut. E. Kidson, of New Zealand, who has distinguished himself as a magnetician in the service of the Carnegie Institution of Washington. Maj. H. G. Lyons, R. E., formerly director general of the Egyptian Survey Department, took charge of the Mediterranean area in May, 1915. A professor of meteorology to the Royal Flying Corps has been appointed, the appointee being Lieut. (now Maj.) G. I. Taylor, Royal Flying Corps, who was previously Schuster Reader in Meteorology. The special meteorological service organized by the Italian Army has published several bulletins dealing with the military relations of meteorology and climatology. Among the subjects so far considered are the climates of the districts in the war zone, and details regarding avalanches, with lists of places specially subject to them. The United States Signal Corps, with the co-operation of the Weather Bureau through the National Research Council, has also organized an extensive meteorological service in France. Maj. (formerly Supervising Forecaster) E. H. Bowie has charge of the forecasting, and has associated with him Lieut. R. H. Weightman. Maj. (formerly Prof.) Wm. R. Blair has charge of the field observations, specially the aerological observations with pilot and sounding balloons for the benefit of aviators and artillerists. He also has associated with him Capts. A. H. Thiessen and W. G. Reed, and a considerable number of other Weather Bureau employees who are now attached to this important

[5] Sir Napier Shaw.

[6] See section on *Weather Forecasting*, p. 26 below.

military unit. A somewhat similar service, in the interest of naval meteorology, is being organized by Lieut. Comm. Alexander McAdie, U. S. N., with whom likewise are associated a number of Weather Bureau men, forming a nucleus for the development of a more extended service of a meteorological nature.

THE ATMOSPHERE.—*General.*—With the composition of the atmosphere in which he flies, the aviator has no particular concern. He may be interested in the nitrogen as a source of nitric acid and of nitrates, the chemical constituents of gunpowder and of fertilizers. The water vapor becomes critical when condensed into clouds or rain. The oxygen plays an important part in engine performance, but its amount becomes of direct concern to the pilot only when, at great altitudes, insufficient oxygenation of the blood may lead to temporary physiological disturbances. It is the physical conditions of the atmosphere, notably temperature, pressure, air movement, which are of immediate interest in aviation.

Temperatures in the Free Air.[7]—In the average, the temperature of the free air falls with height. The mean rate of decrease is 1° F. in 300 feet of ascent (10° F. [5.56° C.] per km.). Therefore, if the temperature at sea level happened to be 50° F., the freezing point (32° F.) might be expected at about 1 mile above the surface.[8] At a height of about 5 miles, the freezing point of mercury (—40° F.) is reached.[9] Temperatures between 0° and —40° F., varying with

[7] Information regarding the methods of obtaining temperatures in the free air may be found in the newer text books on meteorology.

[8] $50° - 32° = 18°$; $300 \times 18 = 5{,}400$ feet.

[9] Many hundreds of observations in central Europe, made with ballons-sondes and manned balloons, have given the following mean temperatures at various altitudes in the free air, up to the present highest flying levels:

Altitude		Temperature	
Miles	*Kms.*	° *F*	° *C*
(0.0)	(0)	(48.9)	(9.39)
0.6	1	41.0	5.00
1.2	2	32.9	0.50
1.9	3	24.8	— 4.00
2.5	4	15.4	— 9.22
3.1	5	4.3	—15.39
3.7	6	— 7.6	—22.00
4.3	7	—20.2	—29.00
5.0	8	—33.2	—36.22

In converting statute miles into kilometers, and kilometers into statute miles, the following simple rules, which give results sufficiently accurate for all ordinary purposes and were suggested by Prof. J. B. Woodworth, of Harvard University, will be found useful.

A. To convert statute miles into kilometers:

the season and with the weather type, may be expected at the present highest flying levels. There is a seasonal difference of temperature between summer and winter in the free air, but it is less than at the earth's surface. At about 6 miles the mean winter temperature is in the vicinity of —70° F. (—56.67° C.), and that of summer, —60° F. (—51.11° C.). This decrease in temperature continues up to the level of the highest clouds (about 6 miles = 10 kms.), beyond which, so far as observations have extended, there seems to be no further decrease of temperature with height. There may even be a slight increase. This upper layer (*stratosphere*) is beyond flying limits. The lower layer (*troposphere*) is the one with which we are concerned.

Near the earth's surface (i. e., within 2 miles or so), the rate of change of temperature vertically is very irregular. It may be more, or less, rapid than 1° F. in 300 feet; there may be no change, or there may even be a rise of temperature with height. On calm, clear nights, in the colder months especially, it very often happens that the temperature distinctly rises for a time with increasing elevation. There is then a warmer layer of air over a colder one. This condition is known as an "inversion of temperature." It is associated with cool or cold, more or less stagnant lower air; is often accompanied by a fog, and quickly disappears if a wind springs up, or when the morning sun is strong enough to warm the earth's surface and the lower air. When flying up through such an "inversion," the aviator will find the temperature rising at first, and then falling at something like the usual rate. Above the stagnant lower air, also, the machine will enter moving currents. Inversions are not limited to the earth's surface. They are frequently found aloft, especially above cloud layers. The kind and amount of change of temperature vertically is an indication of atmospheric stability or instability. When the temperature decreases rapidly with increasing altitude, the air is unstable, and vertical currents will occur. When the temperature increases with ascent, the air is stable, and there is little vertical movement as far up as the inversion extends. In flying through successive layers of air, many different temperature conditions may be met with, but on the average, as stated above, the temperature falls at a rate of 1° in 300 feet.

Pressure.—For several reasons, pressure is the most important meteorological element in aviation. (1) Observations of pressure make the determination of altitude possible; (2) the resistance of the air and the performance of the engine to some extent depend on

To the number of miles add ½, 1/10, and 1/100 of that number.

B. To convert kilometers into statute miles:

To ½ of the number of kilometers, add ⅛ of that number. If, for every 1,000 miles, 4 be subtracted from the final result, still greater accuracy is secured.

pressure;[10] (3) pressure and its changes control air movements and, through these, the other weather elements, such as temperature, humidity, cloudiness, rainfall. The ocean of air and the ocean of water are alike in many ways. The deeper the diver descends below the surface of the water, the greater the pressure he has to endure. The deeper man is submerged in the atmosphere, i. e., the more air there is over him, the greater the weight or pressure of that air. The decrease of pressure aloft, with decreasing depth of immersion in the ocean of air, may produce certain physiological effects which may, usually temporarily, cause discomfort or perhaps even disability.[11] Air, like water, adjusts itself to differences of level; "seeks its own level." Moving air (wind) is making such an adjustment. Atmospheric pressure over the higher latitudes of the earth's surface usually changes considerably from day to day. In the construction of weather maps for the purposes of weather forecasting, the meteorologist must know the pressure conditions over a large area. In flying, it is the pressure which gives the aviator his altitude.

The mercurial barometer is the standard instrument for determining pressure in all accurate meteorological work. It is, however, wholly unsuited for use in flying. It is heavy, difficult to carry, very delicate, and its readings require many corrections.[12] The height of its mercury column (in inches or millimeters) indicates the pressure of the air. The aneroid ("without fluid") barometer is portable, is not so easily broken, and does not require so many complicated corrections. Hence it is a much more convenient instrument, but is less accurate. An increase in pressure compresses the corrugated top of an elastic metallic vacuum box, and a decrease in pressure allows the box to recover again.[13] A spring helps the action, and a simple

[10] The power of the engine depends on the amount of air, and on the corresponding amount of fuel, taken into the cylinders at each explosion, i. e., on the density of the air. This is dependent on the pressure and also on the temperature. Under ordinary conditions when the pressure is higher, or the temperature lower, the performance of the engine is better. When the pressure is lower, or the temperature higher, the tendency is the opposite. On a hot day the performance near the surface would be somewhat like that at a higher altitude on a normal day. When the sea level pressure is low, the engine works under conditions similar to those somewhat above the surface on a day with normal pressure. There is, however, compensation for the decrease in the power of the engine at great altitudes in the lessened resistance of the air when the density is lessened. And there comes in also the effect of the cold at great altitudes in causing poor ignition.

[11] Information on this subject may be found in numerous writings on mountain climbing and on aeronautics; also in medical works. See further J. Hann: Handbook of climatology, v. 1, 2d ed., translated by R. De C. Ward, New York, 1903. pp. 224-230.

[12] For information see Charles F. Marvin: "Barometers and the measurement of atmospheric pressure." Circular F, Instrument Division, U. S. Weather Bureau.

[13] Several vacuum boxes may be used.

system of arms and levers magnifies and changes the vertical movements of the box cover into a circular movement of a needle around a dial. This dial is graduated into inches and tenths of inches, or into millimeters, by comparison with a standard mercurial barometer. Aneroids should frequently be compared with mercurial barometers in order to insure the greatest possible accuracy. They are more reliable in showing changes of pressure than absolute pressures. They need careful handling; should if possible be kept from extreme and sudden temperature changes, and from all violent knocks or jars. As the mechanism lags behind the pressure-change because of unavoidable defects of elasticity, it follows that during a rapid ascent the readings are likely to be too high, and during a rapid descent they are likely to be too low. This would give too low an altitude in ascending and too high an altitude in descending. It is obvious that this lag should be absolutely the minimum obtainable.

Aneroids may be made self-recording, and are then known as barographs.[14] The changes in pressure are recorded on a sheet of paper wound around a cylinder driven by clockwork inside. Barographs are made of various sizes, even down to those which are small enough to be carried in the pocket.

It is in the determination of altitudes that barometers have their chief use in aviation. If the difference in pressure between two places, one higher than the other, be known, the difference in the elevation of the two stations may be determined. The pressure at the higher station will be less because there is less weight of air upon the barometer there. Between the two stations there is a column of air whose height corresponds to the difference in pressure at these stations. If the height of this column be known, the elevation of the upper station above the lower is known. Unfortunately for easy memorizing, the heights of the air columns corresponding to given pressure-differences vary, depending upon the density of the air, upon the temperature, pressure, humidity, etc. Formulæ are available for use in determining the differences of height where the various required elements are known. Published tables, however, make the solution of the problem much simpler, and are widely used.[15] When aneroid barometers are provided with a scale to show altitudes as well as pressures, a certain length of air column, at a selected mean temperature and mean pressure, is taken as the standard. In other words, it is assumed that for a pressure change of, say, 1 inch, or 25 mm., the corresponding height of air column is so many feet, or meters. Clearly, whenever the pressure or temperature, or both, at the time of

[14] See "Barometers and the Measurement of Atmospheric Pressure."

[15] See e. g., Smithsonian Meteorological Tables, or "Barometers and the Measurement of Atmospheric Pressure."

any observation differ from the selected mean, there will be an error in the resulting altitude as indicated on the altitude scale. This error may amount to several per cent. The aviator, however, does not have to know his altitude with absolute exactness. In the newest aneroids the errors are being gradually reduced.

For ordinary use in aviation, the " altimeter " replaces the aneroid barometer. The " altimeter " is an aneroid graduated to show height instead of pressure. It should be sensitive, and have an open scale, easily read. A good " altimeter," if properly adjusted, is sufficiently accurate for all ordinary flying purposes. No determination of altitude, it may be worth noting here, can be really accurate unless there are two *simultaneous* readings of pressure, one at the lower station, whose altitude above sea level is known, and the other at the upper station, or in an aeroplane. In addition, the temperature of the intervening air column should be known. This is usually taken to be the mean of the temperatures at the upper and lower stations, observed simultaneously. The altitude of an aeroplane, as indicated by aneroid, depends on the difference of pressure between the height at which the machine happens to be and the pressure at which it left the ground. As the surface pressures may very likely vary during a flight, it is easy to see that the supposed altitude of the machine may differ appreciably from its actual altitude provided these pressure changes have been considerable. This error can not be provided for under ordinary conditions of war flying. If the instrument be carefully adjusted to the pressure and altitude at the starting point, the readings may be assumed to be substantially accurate.[16]

In addition to the direct use of barometers in the determination of altitude, they are also important to the aviator in showing the distribution of pressure over the earth's surface. It is this which determines wind movement. When barometer readings are reduced to sea level, and plotted on a map, differences of pressure are seen to exist. Places that have the same (sea level) pressure are joined by lines known as *isobars* (equal pressure). Isobars are essentially like the contour lines on a topographic map. On the daily weather maps of the United States and Canada isobars are drawn for every 0.10 inch.[17] Any weather map shows the existence of regions where the

[16] In case the ''altimeter'' becomes broken, and an ordinary aneroid, graduated only for pressures, is available, it may be of help in an emergency to know that about 1,000 feet of altitude roughly correspond to about 1 inch of pressure-decrease. This is a very crude and therefore inaccurate means of judging heights, but it may serve for lack of something better.

[17] On the English maps isobars are drawn for intervals of 5 mbars. (millibars). One thousand millibars equal 1 bar. The bar is equal to the pressure of 29.531 inches (750.1 mms.) of mercury at 32° F. (0° C.) and at latitude 45°. It is equivalent to a pressure of 1 megadyne per square centimeter, i. e., to 1,000,000 dynes

pressures are relatively low.[18] These areas are surrounded by more or less circular or oval isobars; are marked LOW, and are depressions in the atmospheric topography. There are other areas of relatively high pressure; also more or less circular or oval in shape, and marked HIGH. These are elevations in the topography of the atmosphere. A weather map is to be regarded essentially as a contour map. It shows elevations and depressions; hills and hollows. If there were no disturbing causes, the pressure at sea level would everywhere be the same; the atmosphere would be at rest.

A glance at any weather map will show that the distances between the isobars vary. As the pressure difference between any two adjacent isobars is always the same (0.10 inch or 5 mbars.), it follows that where the isobars are close together the pressure is observed to rise or fall rapidly as one crosses them, and where they are far apart the rise or fall is slow.[19] The *barometric* or *pressure gradient* is steep or gentle; strong or weak. In other words, just as crowded contour lines show steeper slopes on a topographic map, so crowded isobars on a weather map show steeper slopes of the isobaric surfaces in the atmosphere. And as water on the earth's surface flows down hill-slopes and into hollows, so air, obeying a similar impulse, tends to flow away from areas of higher pressure and toward areas of lower pressure. If left to itself, the wind would naturally blow directly down the atmospheric slopes along the shortest path from one isobar across to the next lower isobar, and so on until it reached the bottom of the slope (LOW). It would follow the line of most rapid pressure decrease, crossing the successive isobars at right angles. The winds would therefore blow directly out and away from centers of higher pressure, and directly into centers of lower pressure. They would be radial.

The Wind in Relation to Pressures at the Earth's Surface.—The winds are unable to follow the line of the pressure gradient. The fact that the earth rotates causes winds in the Northern Hemisphere to be deflected to the right of a direct path, i. e., the tendency is for them to blow parallel with the isobars rather than directly across them.[20] Friction comes into play and resists the tendency of the wind to blow more and more to the right. The differences of pressure produce the slope (gradient) on which the air moves. The rotation

per square centimeter. Hence a *millibar* is equivalent to 1,000 dynes per square centimeter.

[18] See later section on *Weather Forecasting*, p. 26.

[19] It seems better to reserve the expression "pressure change" for the change in pressure at one and the same point within a stated interval of time, e. g., "the 24-hours pressure change." United States forecasters map the 24- and 12-hour pressure changes and use them constantly in forecasting.

[20] Ferrel's Law: The amount of deflection depends upon the velocity of the wind and upon the latitude.

of the earth deflects the wind (to the right in the Northern Hemisphere). Friction opposes varying resistances. The resultant surface wind directions are neither directly down the slope, nor parallel with the isobars, but somewhere between the two. Around an area of low pressure in the Northern Hemisphere the wind therefore blows in and around to the left. The system is an inward spiral, counterclockwise, and is known as a *cyclonic* wind system. In the case of a similarly situated high-pressure area the winds blow out, and around to the right. This is an outward clockwise spiral—an *anticyclonic* wind system.[21]

So well defined are these systems of winds that one of the best-known laws of meteorology has been based upon them. *Stand with your back to the wind (in the Northern Hemisphere) and the pressure will be lower on your left hand than on your right.* This is Buys-Ballot's Law, and its formulation dates from 1857. It is a necessary consequence of the earth's rotation. Naturally, irregularities of pressure distribution, the varying effects of topography, and other causes, often cause local winds to depart from the general rule. If the minuter details of pressure could be observed and charted, most of the apparent "exceptions" would probably be seen to be in agreement with the rule.

Regarding wind velocity, it is easily inferred from what has been said above that where the isobars on a weather map are close together, there the winds will have higher velocities, and where the isobars are far apart, there the winds will be gentle. For surface winds which are greatly affected by friction, no satisfactory definite rule can be given for a relation between wind velocity and pressure gradient. At moderate altitudes, however, it is possible, within certain limitations, to calculate both the direction and the velocity of the air currents.[22] One thing is very clear. Very small pressure differences can produce high winds.

Wind velocity may be estimated, and then expressed according to an accepted scale, such as the well-known Beaufort Scale dating from the early part of the last century. The equivalents of the numbers of the Beaufort Scale, in miles an hour and in pressure per square foot, have been determined.[23] On American weather maps, wind velocity is given in miles an hour in the printed table. On English maps, the numbers of barbs on the wind arrows indicate the velocity accord-

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[21] These whirls develop centrifugal components which come into play in modifying the wind directions and velocities. In the case of a LOW, the effect of the gradient is balanced against the effects due to the earth's rotation and the centrifugal component of the whirl. In a HIGH, the gradient and the centrifugal component of the whirl are balanced against the earth's rotation.

[22] See later under *Forecasts of Wind Direction and Velocity Aloft*, p. 27.

[23] See e. g., W. N. Shaw: Forecasting weather. London, 1911. pp. 30-31.

ing to the Beaufort Scale. On the French maps the barbs indicate the velocity according to a scale of 4, but the tabulated observations use a scale of 9.

In the United States, meteorologists commonly measure wind velocity by means of the Robinson cup anemometer.[24] This instrument is unsatisfactory for aviation purposes because it does not indicate the gustiness of the wind, which is usually much more important than mean velocity. A better instrument for this purpose is the Dines pressure-tube anemometer, much used in England. In this the varying wind pressure and suction raise or lower a float whose changes of level are recorded on a chart wrapped around a drum driven by clockwork.[25]

Even the steadiest wind is gusty. Observations with self-recording anemometers of the Dines and other patterns, show that gustiness varies greatly with different wind directions and in different places.[26] The Dines anemometer may also be adapted to show wind direction by providing it with a wind vane.

In war flying aviators have no occasion to make their own instrumental observations of any weather element. Such data are supplied by the military field weather services. It is, however, desirable that each aviator should have some knowledge of the essential meteorological instruments, so that, if necessary, he may read them himself.

Air Currents Above the Surface in Relation to Aviation.—There are no "holes" in the air. The term is misleading and inaccurate. It conveys the idea of a vacuum or of a partial vacuum; of a local deficiency of air which does not exist. The idea of "holes," of "pockets," and of "dead spaces" comes from the fact that there are often sudden changes in the relation of the aeroplane to the air current by which it happens, at the moment, to be supported. Such a failure in adjustment may be caused by a sudden change in the direction or in the velocity of the general currents in which the machine is flying; by encountering ascending or descending air movements; by flying across atmospheric waves, and in other ways. Horizontal gusts and lulls produce a temporary change in the pressure of the air against the machine—i. e., in the velocity of the aeroplane *through the air,* causing a momentary change in the lift. The resulting effects depend on whether the aeroplane is moving with or against the wind, and on its relative velocity with respect to this wind. If the machine

24 See "Instructions for the installation and maintenance of wind measuring and recording apparatus," Circular D, Instrument Division, U. S. Weather Bureau.

25 A description of this instrument will be found in the Observer's Handbook of the British Meteorological Office.

26 The *fluctuation of the wind* is the difference between the average maximum velocity reached in the gusts and the average minimum velocity in the lulls. The ratio of the fluctuation to the mean velocity is the *gustiness.*

happens to fall rapidly, there is apparently a "hole." Again, when the angle at which the wind strikes the machine changes, there is also a change in the lifting power. If the angle becomes more upward, the machine will rise; if more downward, it will fall. Should a machine suddenly come into a current of air having exactly the same direction and velocity as itself, it would be in a "dead space." Under conditions of active vertical air movements an aviator may pass rapidly from an ascending to a descending current. His machine will then descend. A descending movement does not, however, continue until it strikes the ground vertically. It must obviously become more and more horizontal as it nears the surface. Again, a pilot may find his machine just on the dividing line between an ascending and a descending current. In such a situation there will inevitably be tips and bumps. Various combinations of such conditions as those here suggested explain "holes" and "pockets" and "bumps."[27]

A. General Air Movements Essentially Horizontal: Layers.—The atmosphere, in spite of its being well mixed vertically, has more or less of a layer structure (stratification). Records of self-recording instruments sent up with ballons-sondes, and the courses of these ballons-sondes and of pilot balloons[28] have shown that these layers often differ considerably from one another in direction of movement; in velocity of movement; in temperature; in humidity; in cloudiness. Extended cloud sheets, for example, are often found in damp layers which have been cooled to their dewpoint, while above and below the sky may be cloudless. The rates of change of temperature vertically often vary a good deal in different air strata. It is when these rates are average that the rate of decrease of temperature of 1° F. in 300 feet, referred to in an earlier paragraph, is obtained. In flying, aviators thus often pass from one layer to another whose direction, or velocity, or both, may be different. A change in the adjustment of the machine becomes necessary. The machine may rise; it may fall slowly or rapidly as conditions may determine. Endless combinations are conceivable. No set rules can be given. Nor can the

[27] Humphreys, William J. "Holes in the Air." Rept. Smithson. Instit. for 1912, pp. 257-268.

[A consideration of various types of air movements which the aviator is likely to meet. The classification is perhaps somewhat too detailed and the terms used, such as "aerial cataract," "breakers," "cascades," are likely to cause unnecessary alarm in a novice. The article is a suggestive one for the use of the teacher. The present writer has drawn on Prof. Humphreys' discussion in the paragraphs which immediately follow.]

[28] Pilot balloons are gas-filled spherical rubber or paper balloons of small diameter and without instrumental equipment. They are released for the purpose of determining direction and velocity of the upper currents, and have been followed to great distance and altitudes by means of special theodolites.

weather forecaster, from the daily weather map, tell definitely what the conditions of atmospheric stratification will be. Cloud observations help. Pilot balloons, when such are available, furnish the best means of determining the direction and the velocity of the higher air currents. Adjacent strata differing so greatly and so suddenly in direction and velocity from one another as to be dangerous, are rare. There is usually a gradual transition. Hence, if a strong current of air from one direction is above or below a strong current from an opposite direction, there is likely to be a layer of *comparatively* quiet air between. If difficulty is being experienced in any given layer, it should be remembered that the stratification is essentially horizontal, and a change of altitude will very likely bring better flying conditions. The maximum diversity between adjacent air strata occurs in connection with stormy weather, or when the weather is changing from fair to stormy.

Waves.—Friction between atmospheric strata moving over and differing from one another in density, direction, velocity, etc., often produces waves along the contact surface. These are essentially similar to the waves produced on water by wind. Balloons, traveling in such a wave layer, rise and fall with the waves. Von Helmholtz (1889) showed that atmospheric waves may have a length of hundreds of meters. When the moisture conditions are favorable, clouds form along the crests of these waves, while the troughs are unclouded or have thinner clouds in them. Under these circumstances, long parallel lines or rows of cloud are seen stretching across the sky. Sometimes these waves are only faintly developed, or appear in different parts of the sky. The lines of cloud may be continuous, or may be formed of separate small clouds, arranged in rows. The latter indicate a crossing of the layers, and the condition is similar to that of a "choppy sea," when long rollers are broken up into shorter and less regular waves by a change in the wind direction. Often a sheet of cloud is thrown into waves, the sky being wholly overcast, but the separate waves being distinguishable. Waves may occur at many altitudes. That atmospheric waves are often present when there are no clouds to indicate them is evident from the experience of aeronauts and of aviators, and from the records of delicate self-registering barometers, which at times show the passage, over the instruments, of regularly recurring oscillations of pressure. Flying along a wave level is apt to be "bumpy." If the machine is progressing against the waves, the irregularity of motion is greatest on account of the rapid changes in vertical motion. On the other hand, if the machine is flying with the wave motion, a smaller number of ascents and descents is experienced in the same interval of time. As the wave layer is an essentially horizontal stratum,

relief can be secured by driving the machine up or down into a less disturbed region.

B. Local Convectional Currents, Essentially Vertical, Due to Thermal Controls.—Ascending currents are common on fine warm days, especially in summer. They are caused by the heating of the earth's surface under sunshine. The warmed air, being light, rises, as a cork rises through water. These rising currents are most common over mountains and hills, up whose slopes there are usually active ascending air movements during the warmer hours of fine summer days, and over open unforested areas. A freshly plowed field, of dark soil, is likely to be better warmed, and hence to be the seat of greater activity of ascending currents, than a field covered with crops or grass. When the warmed air rises high enough, and reaches its dew-point temperature, the familiar fine-weather clouds of summer are formed, with their flat bases and bulging, convex tops (cumulus). These clouds are in many respects the most interesting from an aviator's point of view. They are " the visible tops of invisible ascending columns of air." As seen from above, "cumulus clouds give the appearance of a very wild and rocky country; large cumuli resemble snow mountains."[29] They are naturally associated with more or less turbulent (" bumpy ") conditions, of descending as well as of ascending currents. These conditions may extend to several thousand feet (10,000 feet more or less) above the surface. The base of cumulus clouds has a mean height above the surface of 4,600 feet (1,400 meters); while the tops average 5,900 feet (1,800 meters). Aviators report that " bumpy " conditions often occur on fine summer days even when there are no cumulus clouds. The explanation is that warm ascending currents are present, just as they are under cumulus clouds, but the rising air has not reached its dewpoint and hence remains clear. Probably, however, the most active ascending currents do not occur without cloud formation. It is easy to understand why fine, warm summer days, which would seem, at first thought, to give peculiarly steady flying conditions, are so " bumpy." Observations by means of kites and balloons have shown that the rate of ascent of the warm currents is often 10 to 12 feet per second. In thunderstorms this ascent is much more rapid.

All the air on a warm day can not be ascending. Descending currents are also inevitable. They may be met with in the clear space around the clouds; over the less easily warmed surfaces, such as water, swamps, damp fields, and forests; and to some extent also intermingled with the rising movements. There is thus the difficulty of finding the machine tipping because it is partly in an ascending and partly in a descending current; or because it is between a rising or a descending current and the more or less quiescent air surrounding. Or, the

[29] Lieut. Douglas Taylor, Royal Flying Corps.

aviator may run suddenly from an up-current into a down-current, and vice versa. Quick adjustments are often necessary. Under normal fine-weather conditions, however, such irregularities of air movements are not likely to be serious. It is well to remember that the turbulence of the lower air on a warm summer day is greatest during the warmer hours, and that the early morning and late afternoon hours are usually less cloudy and less "bumpy." During the warmer hours the surface wind also has a higher velocity, and is apt to be irregular and gusty, while the earlier and later hours are likely to be relatively calm. This is a practical point in connection with landing. The facts above noted about the surfaces over which there are apt to be the most active ascending, and those where there are likely to be descending movements, are also of practical value in flying. On clear, quiet nights, descending currents are likely down mountain slopes and in deep valleys, replacing the up-slope currents of daytime.

Overcast days do not show the phenomena of local convectional air movements which have here been considered.

C. Effects of Topography on Air Movements, Combining Both Horizontal and Vertical Elements, Due to Mechanical Controls.—Wind near the ground is naturally variable and gusty. It is often forced to ascend or descend by the irregularities of the surface. Even where this surface is level, the lower air is retarded by friction and there is more or less descent of the faster-moving stratum just above. This results in a vertical interchange of air, of an irregular character. The extent to which such movements develop depends upon the amount of friction below and upon the relative velocity of the air currents. The surface wind is generally less gusty at night, hence this is as a rule the best time for flying. Sudden changes in the relation between the wind and the air currents just above the surface may be locally produced by alternating land and water surfaces, resulting in differing amounts of friction. Irregularities on the earth's surface cause many tangles, eddies, or waves in the moving air. Forests, buildings, all elevations or depressions, disturb the uniform flow of the lower air. In rising over an obstacle, such as a mountain range, or a hill, the air currents are likely to be congested, and their velocity increased. Winds are therefore usually stronger over mountains and hilltops, partly for this reason, and partly because of the faster movement of the upper currents. Again, when air rises over an obstruction such as an isolated hill, for example, it may be forced into a series of waves to leeward, at the level of the hilltop. Such standing waves have been noted in the case of several mountains,[30] being sometimes visible because clouds form at the crests of the waves. There may be two or

[30] Green Mountain, on the island of Ascension, for example, as reported by the late Prof. Cleveland Abbe.

three successive waves, each one farther from the mountain top, and each one smaller than the last. These wavelike movements may cause temporary and local "bumps."

Prof. W. J. Humphreys, among others, has called attention most recently to the eddies which are likely to form on the leeward slopes of hills or mountains. The air comes down on the lee side in "cascade-like falls," which are more rapid the stronger the wind. Eddies are likely to develop close to the surface, the lower member of the eddy blowing up the slope, i. e., directly opposite to the general wind movement, which is downward. There are vertical down-currents on the down-slope, and vertical up-currents on the up-slope side of these eddies. The safe course is obviously to keep above the eddies and other irregularities of flow of the lower air. Eddies of this kind, combining both horizontal and vertical motions, are common close to the lee side of many obstructions; sometimes also, to a less degree, on the windward side. Aviators have many times reported active vertical currents in the lee of forests. In landing during strong winds, the close vicinity, and especially the lee side of mountains, cliffs, hills, forests, in fact of obstructions of any kind, are likely to have disturbed wind movements. Decreased wind velocities will usually be found in sheltered localities, such as valleys transverse to the wind; as well as in forest clearings, where the wind is, however, likely to be very changeable, and to leeward of extended forests and of hills. In general, of course, by flying at greater heights, steadier winds will be found. The effect of surface irregularities upon the winds aloft is more marked, and extends farther, the greater the wind velocity.

Clouds.—Clouds are among the aviator's most serious meteorological handicaps, but they have two very practical uses: (1) They show the direction of the higher air currents, and (2) they are useful as *weather* prognostics. Accurate determination of cloud movements requires the use of a nephoscope and of a theodolite,[31] but somewhat rough and fairly satisfactory observations may be made non-instrumentally. A cloud patch, or some easily identifiable point in a cloud sheet, near the zenith, should be brought in line with the corner of the roof of a building, with the end of a branch of a tree, or with some other fixed object. As the cloud moves, the compass direction of its movement can roughly be determined. To have even such crude observations as these of value, some knowledge of cloud heights is neces-

[31] Abbe, Cleveland: "Treatise on Meteorological Apparatus and Methods." Ann. rept. Chief Signal Officer for 1887, Appendix 46. Washington, D. C., 1888.

Clayton, H. H., "Discussion of the cloud observations made at Blue Hill Observatory, Mass., U. S. A.." Ann. astron. obsy. Harv. Coll., v. 30, pt. IV, 1896. Cambridge, Mass., 1896, 4°. pp. 273-278.

sary,[32] so that it may be clear at what altitudes the various wind directions, indicated by the observed cloud movements, will be encountered. Sometimes cloud directions for two or three different levels may be determined at the same time. The lower clouds, being nearer, seem to move faster, while the upper clouds, although actually traveling at greater velocities, apparently move much more slowly. It is impossible, therefore, without instrumental observation, to gain anything more than an indefinite, and sometimes indeed even a misleading, idea of the velocity of the upper currents. Cloud perspective also is a puzzling matter, but practice in watching cloud movements will soon enable anyone to make fairly accurate observations.[33]

A careful study of clouds as weather prognostics involves a long period of discriminating individual local observation and record. A few very general suggestions are here made. Further information may easily be secured by those who desire it.[34] Detached, scattered, isolated clouds are as a whole characteristic of fine weather. When, however, they become more numerous, spreading over the sky; when they arrange themselves in long parallel rows, giving the appearance of waves, and when they are followed by sheets of cloud, wet and perhaps stormy weather is indicated. Cloud sheets gradually spreading from the western horizon across the sky toward the east; becoming lower and darker; with rings (haloes, coronæ) around sun or moon; or with a "wet" moon and a "watery" sun, are storm prognostics.[35] *Wave* sheet clouds are still better rain prognostics. Even the general path of a storm with reference to the observer can often be foretold by cloud observation. For example, if thickening "mare's tail" cirri are seen diverging from the west or southwest they may serve as indications of a storm approaching from that quarter, which, as it moves eastward, is likely to affect the weather at the observer's station. On the other hand, when such clouds are seen diverging from the north, the storm is probably passing by to the eastward too far away to control the local weather.

Fog and low cloud sheets are very unfavorable for the aerial observer. They either make observation altogether impossible, as in the case of a fog, or they oblige him to fly so low, beneath the cloud, that he is within close range of the anti-aircraft guns, as in the case of stratus

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32 See "Atlas International des Nuages;" also "Illustrative Cloud Forms for the Guidance of Observers in the Classification of Clouds," U. S. Hydrographic Office; also recent textbooks.

33 A simple discussion will be found in Ralph Abercromby: "Weather," 1887, pp. 87-92.

34 See H. H. Clayton, *loc. cit.*; also W. J. Humphreys, "Some weather proverbs and their justification," Pop. sci. mo., New York, May, 1911, pp. 428-444.

35 At Blue Hill, Mass., cirro-stratus usually precedes rain by about 13 hours; alto-stratus, by about 6 hours.

and nimbus clouds.[36] Isolated, detached clouds, on the other hand, may interfere with reconnaissance work, but do not stop it altogether. The clouds here selected for brief discussion, from a practical point of view, are those which are most critical for the aviator. They are fog (not classed as a cloud by meteorologists), the lower sheet clouds, and the thunderstorm cloud.

Fog.—Typical land fog, which is the kind of fog that most frequently affects flying, occurs when there is little or no wind; under clear skies; chiefly on autumn and winter nights, although it is frequent throughout the year. In summer it usually "burns off" soon after sunrise; in the colder months it may last all day. This is a point worth remembering by aviators. The thickness of a fog sheet varies greatly according to conditions of weather and of topography. It may be only a few feet; it may be several hundred feet in a mountainous country. Typical land fogs form first, and are thickest, in the valleys and on lowlands. Hence they are often called valley and lowland fogs. When flying above a thick, widespread, dense fog sheet, it is impossible to see the surface. Hence it is essential that the distance above the ground should be known within very close limits. These fogs are favored by high pressures, because then the sky is apt to be clear and the wind light. Apart from the fog, the flying conditions are very favorable. The lower air is then very stable.[37] Fogs are formed in other ways, also, as in the case of damp winds blowing in from the sea (marine fog conditions), or when the mixture of different air currents leads to condensation. Such fogs may last for days. Coast fogs are generally more frequent in summer, while typical land fogs are more characteristic of fall and winter.

Lower Sheet Clouds.—At an altitude averaging less than 3,500 feet above the surface, but often reaching nearer, there is a high fog (*stratus*) whose relations to flying are much the same as those of ordinary fog. In fact, stratus cloud is essentially, as its definition puts it, "lifted fog in a horizontal stratum." It is, however, usually much thicker than an ordinary fog; does not rest on the ground, and lasts longer. It may be a typical fog which has been actually lifted from the ground, or it may have formed by mixture or by condensation between cool and warm air currents. There are, in fact, all gradations between fog and stratus cloud. It is common in winter, at night, and in higher latitudes. Although often mistaken for a rain cloud, stratus does not give precipitation, but it may precede rain or

[36] The complete classification of clouds, with illustrations and descriptive text, will be found in the "Atlas international des nuages" and in "Illustrative cloud forms for the guidance of observers in the classification of clouds," U. S. Hydrographic Office.

[37] See important paper by Maj. G. I. Taylor, R. F. C.: "The formation of fog and mist." Quart. journ. Roy met. soc., July 1917, 43: 241-268.

snow. Its vertical thickness varies greatly, and may reach a few hundreds of feet. It does not "burn off" as typical land fog usually does, and may persist for several days. Seen from above, stratus presents the appearance of a "sea of clouds." Its top may be very even, or may be in waves or billows. Reconnaissance work is practically impossible, but stratus is not a storm cloud and flying *above* it presents no special meteorological difficulties. Orientation is, of course, difficult or impossible. If the cloud sheet is not too thick, the upper surface of it, under certain favorable conditions, indicates the topography beneath, rivers and valleys appearing as depressions and mountains as elevations. This is a practical point worth remembering. Many aviators have been able to get their bearings in just this way. The temperature often increases for a time with ascent above the earth's surface when stratus clouds are present.

The ordinary rain cloud (*nimbus*) is another low sheet cloud which is likely to prevent aerial reconnaissance. This is the familiar low, dark blue, structureless cloud from which rain or snow usually falls, and below which broken irregular fragments of "scud" often drift. The base of the rain-cloud varies a good deal in height above the earth's surface. It averages under 6,500 feet (International Cloud Classification), and may be much lower. The Blue Hill results give its most frequent altitude as 2,000 feet. Of its vertical thickness little is definitely known. That it does not extend to great heights is clear from the fact that when openings occur in it, or when an aeroplane flies up through it, higher clouds at elevations of 2 to 3 and up to 5 or 6 miles are often to be seen.[38] Aeronauts and aviators have frequently passed through and above the nimbus at an altitude between 6,000 and 7,000 feet. The duration of the rain cloud depends on the size, development, and rate of progression of the general storm (low pressure) conditions with which it is associated. It may last a few hours. It may, especially in winter, cover the sky for 2 or 3 days. A rising barometer and a change in wind are the usual indications of clearing, from the rain cloud to the broken clouds which follow a storm. Fog, elevated fog (*stratus*), and the ordinary rain cloud are thus all of them serious handicaps in aerial reconnaissance, because they are on or near the surface, and conceal that surface very effectively from above.

There is another sheet cloud, at a considerably greater height, which may be described. This is the more or less uniform sheet of bluish cloud, distinctly higher than the rain cloud,[39] through which the sun

[38] E. g., alto-stratus, cirro-cumulus, cirro-stratus, alto-cumulus.

[39] The highest cloud sheet is the thin, delicate, milky, sometimes net-like *cirro-stratus;* formed of ice crystals; often producing haloes, and usually the first sheet cloud seen in front of an approaching storm. As the height of this cloud is

or moon may be seen faintly, as through ground glass (*alto-stratus*).[40] This cloud usually precedes a general rain by a few hours.[41] It is not itself a rain cloud, but is associated with coming wet weather.

Thunderstorm Cloud.—There are only two cloud types which ordinarily bring precipitation. These are the general rain cloud (*nimbus*) and the thunderstorm cloud (*cumulo-nimbus*). The former gives the persistent rains or snows of a general storm. The latter gives the shorter, usually heavier, and often squally rains (including hail) or snows. Of this type the summer thunderstorm is the obvious example.[42]

In view of its importance to the aviator, the thunderstorm cloud requires further mention. In a previous section (see p. 18) reference was made to the ordinary summer daytime cloud (*cumulus*) produced by local, ascending, warm currents. Aviators know well that under these conditions there is always more or less turbulence, which causes " bumps " in flying. These irregularities of ascending, descending and gently whirling air currents usually offer no serious difficulties. Often, however, the cumulus develops into a thunderstorm cloud (*cumulo-nimbus*), and then all these atmospheric movements are greatly accentuated. The cloud mass becomes extremely turbulent; the velocity of the ascending and descending currents increases; the heavy downpour of rain, perhaps mixed with hail, and the danger arising from the lightning, add to the difficulties. Vertical currents in thunderstorms may sometimes attain a velocity comparable with that of strong surface winds (Sir N. Shaw). In addition to receiving all possible assistance from the official weather forecast, the aviator should know how to predict the occurrence of local thunderstorms. He should, also, know enough about the characteristics of thunderstorms to be able to manage his machine to the best advantage in case he has to fly in one of them.

The typical thunderstorm cloud is an overgrown and greatly developed cumulus cloud. Its base is about three-fourths to 1 mile above the earth's surface, but is usually concealed by the falling rain. Its

between 5½ and 6 miles, it is beyond flying levels. At about 1 mile above the surface a grey cloud, of long rolls, usually covering the sky, often gives the appearance of a sheet but is, in reality, a broken cloud layer with lighter or open spaces between the separate rolls. This cloud (*strato-cumulus*) is common in quiet winter weather, and may persist for days. It makes the day dull and gloomy, and suggests snow or rain, but it is not a rain cloud. From above it has the appearance of "a gently undulating country."

[40] This belongs in the "intermediate" level, between 10,000 and 23,000 feet and averages about 3 miles above the surface.

[41] At Blue Hill Observatory rain follows *alto-stratus* in about 6 hours.

[42] Brief transient showers may, far less frequently, fall from two or three other cloud types, e. g., *strato-cumulus*.

top varies from somewhat over a mile to 5 miles in extreme cases.[43] The thunderstorm type of cumulus has massive, hard rounded tops (thunderheads). The upper edges of these bulging tops very often, especially in the more severe thunderstorms, seem to become soft, and brushed out into a sheet or screen more or less fibrous and raveled (*false cirrus*), which gives the whole cloud, when seen from the side, the shape of an anvil. Or, the upper edges may remain hard and convex, like ordinary cumulus, while the delicate sheet of false cirrus floats around them. When, on a warm, muggy, summer day ordinary cumulus clouds are seen to be increasing in height, growing darker, joining, and especially when the screen or veil of false cirrus forms, local thunderstorms are likely to occur. Further, when a rising mass of cumulus is seen to develop a ring or "collar" just below its top, caution is advisable. When, on the other hand, cumulus clouds break up, flatten and spread, and do not attain great height, the signs are favorable. The extraordinarily rapid upward growth of many cumulus and especially cumulo-nimbus clouds is due, at least partly, to the accumulation of the warm air below until it is able to break up through the overlying more stable strata. When once started, the warm air goes up with a rush, and the cloud may grow thousands of feet vertically in a very short time.

It is much the safer course for an aviator not to fly in a thunderstorm. But if he finds himself in the air when a thunderstorm is approaching, what shall he do? The meteorologist can give him a few suggestions. Thunderstorms in Europe, as well as in the United States, move in a generally easterly direction, at hourly velocities of 20 to 50 miles in the United States, and somewhat less in Europe. At any one time the storm itself has more or less of the shape of a convex lens, the convex side being on the front. The distance through the storm, from front to rear, is small, often less than 50 miles. Many of these storms are so small that it is perfectly easy to fly around them, on their northern or southern margins. On the other hand, the more extended ones, often called "line thunderstorms," may have a front extending roughly north and south for several hundred miles. An aviator can easily fly away from an advancing thunderstorm if such a course will not bring him into the enemy lines. He can also fly over the top of many of the smaller storms, and even over such of the larger ones as have not an excessive vertical development. If the top

[43] Lieut. C. K. M. Douglas, R. F. C., estimates that a height 6,000 feet from top to bottom is an absolute minimum at which cumulus clouds may develop into thunderstorms. On all occasions on which thunder occurred in France in 1916, the height of the cloud from top to bottom was not less than 10,000 feet. (*Journ., Scot. met. soc.*, 3d ser., No. 33, 1916, 17:65-73; or *Monthly Weather Review*, Washington, March, 1917, 45: 93.)

of the storm is so high that he can not fly over it, and no other course is open, the aviator should steer directly through the upper part of the cloud, facing the advancing storm. Usually a few minutes will bring the machine out into the rear of the storm. Thunderstorms are of many types, and of many sizes and degrees of intensity. Hence it is quite impossible to frame rules which will meet every emergency. The possible damage to propellers or to wings resulting from large hailstones is considerably reduced by the fact that hail occurs over limited areas only, and that many thunderstorms produce no hail.

It may be noted that airplanes can and do travel above the levels of many weather conditions (e. g., heavy rain or snow), which might be rather serious handicaps nearer the surface.

Weather Forecasting.—*Surface Conditions.*—Whether in peace or in modern war, the aviator usually has access to the official daily weather forecasts. He is not concerned with the collection of the meteorological data, with their charting, nor with the making of the forecasts. He should, however, understand, in a general way, the broad principles upon which modern weather forecasting depends. He should know how to interpret a weather map for himself. He should be able to make his own individual rough non-instrumental forecast, so that he may be able to fill in the gaps between the hours at which the official forecasts are made, and may not, if out of reach of an organized meteorological service, be perfectly helpless about probable coming weather conditions.

So far as the United States map is concerned, the information can easily be secured.[44] The British maps use millibars (see p. 12) and Absolute temperatures [32° F. = 0° C. = 273° A] instead of inches and hundredths, and Fahrenheit degrees. The French maps use millimeters and centigrade degrees. Some idea of European weather types would be a most important and helpful addition to the meteorological knowledge of any aviator whose duty calls him to service in Europe. This subject has received a great deal of attention on the part of European meteorologists, and may be looked up without much difficulty.[45] The individual who makes his own non-instrumental local weather forecasts, without the help of a weather map, is in the primitive stage of forecasting. He must depend entirely upon weather signs or prognostics. The indications afforded by the systematic changes in direction and velocity of the wind[46] are usually the best guides.

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[44] See "The Weather Map and its Explanation;" and "Wind-Barometer Indications," both published by the U. S. Weather Bureau, Washington, D. C.

[45] See e. g., W. J. van Bebber: "Lehrbuch der Meteorologie," 1890, pp. 317-343. Also: J. G. Bartholomew: "Atlas of Meteorology," Edinburgh, 1899. Plate 32, Text p. 35.

[46] Especially if supplemented by readings of a barometer.

The aviator being especially concerned with the clouds and high winds which are commonly associated with cyclonic storms, will find it well to watch the wind carefully. "Backing winds," from easterly through north to westerly, indicate the approach and passage of a low pressure area on the south. "Veering winds," from easterly through south to westerly, indicate the approach and passage of an area of low pressure on the north. If a barometer is available, the barometric tendency, i. e., the rise or fall, and the rate of rise or fall, should be constantly noted. In general, the approach and occurrence of foul weather are associated with a falling and a low barometer, and of fair weather with a rising and a high barometer.[47] Changes in wind direction mean changes in the distribution of pressure, i. e., in the location of the isobars and hence of the centers of high and low pressure. Changes in wind velocity alone, on the other hand, mean changes in the barometric pressure or pressure gradient, i. e., they mean that the distances between the isobars are increasing or decreasing. In addition to these indications, cloud prognostics, as above suggested, are very useful, and there are many good weather proverbs which, if rightly applied, are helpful.[48]

Forecasts of Wind Direction and Velocity Aloft.—The ordinary forecasts relate only to surface conditions. For the aviator, some idea of the probable wind aloft is obviously also important. Direct observation by means of small pilot balloons, whose course can be followed by means of theodolites, gives excellent indication of the direction and velocity of the upper currents up to ordinary flying heights. This method involves instruments and a certain amount of mathematical calculation, and must therefore be left to the trained meteorologists. Kites have also been used in this work. In the present war, the Germans have evidently made extended use of pilot balloons electrically lighted at night. Direct observation of cloud movements also serves to give definite information of upper air currents. Here again, beyond the simple non-instrumental cloud observations above referred to, the trained meteorologist must be relied on to make use of his nephoscope and his theodolite, and to work out his results.

We come, then, to the already ascertained facts which may be of service in inferring the winds aloft. First, as to direction. For the first few thousand feet up (roughly, perhaps, 4,000-5,000 feet) the direction of the wind usually changes to the right, i. e., in a clockwise direction from that of the wind at the surface. Thus, if the

[47] For the United States, the "Wind-Barometer Table" (see footnote [44]), gives the weather indications associated with various barometer readings and tendencies, combined with accompanying wind changes.

[48] W. J. Humphreys: "Some weather proverbs and their justification," *Pop. sci. mo.*, May, 1911, pp. 428-444.

wind at the surface is SW., the wind aloft may be expected to be more westerly; if the surface wind is N., the direction aloft is likely to be from NE. With increasing distance from the surface, and decreasing frictional resistances, the winds tend more and more to follow the isobars.[49] This condition may be reached at about 1,500 feet, more or less, varying according to circumstances. In fact, different weather types and conditions exert so many varying controls that no hard and fast rule can be laid down. In general, however, it may be said that the shift in wind direction to the right is most marked near the beginning of an ascent, and up to 4,000-5,000 feet the winds may be expected to blow more or less along the isobar. At greater altitudes, above the influence of the surface gradients, the winds tend to come more and more from westerly directions, and easterly directions become less and less frequent.[50] The higher the flight, the greater will be the tendency of the air currents to blow from a westerly point. This is true in Europe as well as in the United States.

On fine, warm days, especially in summer, the lower air and the air somewhat above the surface tend to intermingle as the result of more or less vertical movement. The descending air currents bring down their own directions, and therefore there is a tendency for the surface wind directions to veer to the right during the day. At night, the tendency is to swing back again. This is known in meteorology as the *diurnal variation in wind direction.* In extremely favorable conditions, the shift may be as much as 90°. In the case of a prolonged flight, it must be remembered that the directions of both surface winds and upper currents are likely to be affected by the progression of the isobaric system as a whole.

Secondly, as to the velocity of the air currents aloft. On the average, this velocity increases with increasing altitude, up to the level of the highest clouds. Thus, from measurements of clouds, made at Blue Hill Observatory, Upsala (Sweden), and Potsdam (Germany), for

[49] This is known as the "gradient wind direction."

[50] In this connection the results regarding wind movements at all heights in cyclones and anticyclones obtained at Blue Hill Observatory are very important. See H. H. Clayton: "Discussion of the cloud observations made at the Blue Hill Observatory, Mass., U. S. A.," *Annals Astron. Obsy. Harv. Coll.*, Vol. XXX, Pt. IV, pp. 437-449.

See also chart 21 (Winds at Various Heights as Related to Barometric Pressure at the Ground) in A. Lawrence Rotch & Andrew H. Palmer: "Charts of the Atmosphere for aeronauts and aviators."

For a summary of European results see J. von Hann: "Lehrbuch der Meteorologie," 3d ed., 1915, pp. 528-536, 543-545. In the United States, as shown by F. H. Bigelow and H. H. Clayton, and in central Europe, as shown by Akerblom, the low and high pressure areas of the earth's surface have comparatively little influence on the upper currents in the cirrus level.

example, the mean velocities of air movements at various levels are as follows:

Mean cloud velocities at different heights.

LEVELS	1,600–6,500 feet	6,500–13,000 feet	13,000–20,000 feet
	Mls./hr.	*Mls./hr.*	*Mls./hr.*
Upsala	20.4	19.5	35.8
Potsdam	20.8	23.0	37.8
Blue Hill	21.9	31.8	38.3

Two points may be noted in this connection. Cloud velocities can not be considered as giving accurate indications of air movement because (1) certain cloud types are commonly associated with certain special weather types, and because (2) the upper clouds can only be seen when not obscured by lower clouds. Further, for the aviator, mean velocities are much less critical than gustiness. The above table shows that there is an average increase in velocity from about 20 mls./hr. below a height of a little over 1 mile, to 35 to 40 mls./hr. at 13,000 to 20,000 feet. While the average velocity thus increases aloft, the gustiness usually decreases. Roughly, in the lower 1,000 to 2,000 feet the velocity may be expected to increase " as the height above sea level." If, e. g., there is a wind of 15 mls./hr. at 500 feet above sea level, a wind of 30 mls./hr. may be expected 1,000 feet above sea level, and one of 45 mls./hr. at 1,500 feet. Finally, certain calculations which the aviator is not likely to have the time or opportunity to make for himself make it possible to predict, usually with reasonable accuracy, the wind velocities at about 1,500 feet, and up to, say, 3,000 to 4,000 or 5,000 feet.[51] At and near the earth's surface friction is a large and uncertain element in the problem. But at about 1,500 feet above the surface the effect of surface friction is slight. If the pressure gradient[52] be known, the " gradient-wind velocity " may be determined. This is the ideal wind, calculated from the gradient. It is the air movement needed to balance the pressure gradient. It also depends upon the density of the air, that is upon the temperature and pressure, and upon latitude. Tables have been prepared showing the gradient-wind velocities under varying conditions and at various latitudes.[53]

[51] It is perfectly feasible for the official forecasters to include the direction and velocity of the wind at 1,500 feet in their regular daily forecasts of surface conditions. They have been doing this abroad.

[52] The distance from one isobar to the next lower isobar, measured as nearly as possible at right angles to the two.

[53] Great Britain. Advisory comm. aeronaut. Report No. 9.

Great Britain. Meteorol. Office. Computer's Handbook, Sect. II. (M. O., No. 223).

Gold, Ernest. Barometric gradient and wind force. (M. O. No. 190.)

The calculated results agree fairly closely with the results of observations made by means of kites and balloons. The complete formula is somewhat complicated, but a simple working basis is contained in the following table, adapted from one given by Prof. W. J. Humphreys.[54]

Table for calculating gradient-wind velocity.

Lat.	*Mls./hr.*
40°	$\frac{1900}{M} \times 2.24$,
50°	$\frac{1600}{M} \times 2.24$,
60°	$\frac{1400}{M} \times 2.24$.

M = number of miles between isobars.[55]

In the foregoing calculation it is assumed that the pressure gradient at 1,500 feet is the same as that at the earth's surface, as shown on the weather map. If we had isobaric maps for greater altitudes, the winds at those heights could be predicted. It is known that the arrangement of the isobars, and also the pressure gradients, change fairly rapidly with increasing elevation. For this reason, predictions of gradient-wind velocity (and direction) can not be absolutely relied on, and are limited to the lower few thousand (below 5,000) feet.[56] No definite rules can be laid down. Above the height at which the gradient velocity is reached, very diverse conditions are met. The velocity may increase. It may decrease. Indeed, the gradient velocity itself is not always reached. There is also a curious uncertainty about easterly winds. While westerly winds usually reach their gradient velocities at 1,500 feet or so, and then, as a whole, increase still further up to the maximum flying heights, easterly winds

[54] In Prof. Humphreys' original paper (*Jour. Franklin Instit.*, Phila., March, 1913, p. 234) the values are given for meters/second. The heading over his last column should read "Meters per second," not "Miles per hour."

[55] Formula as given by Dr. John Patterson, Meteorological Office, Toronto:

Lat.	*Mls./hr.*
40°	$\frac{3908}{M}$,
50°	$\frac{3279}{M}$,
60°	$\frac{2900}{M}$,

[56] Expected changes in surface pressure gradients are, to a considerable extent, predictable by the official forecasters.

are very erratic both in changes of direction and of velocity. They do not show the same tendency to give gradient velocities. While westerly winds usually blow stronger at higher levels, easterly winds often decrease in velocity aloft, being then replaced by westerly winds. Easterly winds should therefore be carefully watched.[57]

On fine, warm summer days the surface wind very commonly blows strongest during the warmer hours, while the mornings, evenings, and nights are calm. This is known as the *diurnal variation in wind velocity*. It does not occur on cloudy or stormy days. Obviously, it is to be reckoned with in making a landing. Somewhat above the surface the variation in velocity is just the opposite. During the warmer hours, when the surface winds are blowing hardest, the air currents somewhat above the surface are slackened. At night, when the surface winds die down, the movement is more rapid aloft. The height to which this condition reaches depends on general weather conditions. When conditions are favorable, on hot summer days, it may reach nearly a mile. On such days, therefore, the aviator may find the wind velocity decreasing for a time as he ascends.

Favorable and Unfavorable Weather for Flying.—Summarizing briefly, high pressure conditions are, on the whole, the most, and low pressure conditions the least, favorable for flying.

High pressures as a rule have the advantage of lighter winds; of high and detached clouds; of fine weather. They have the disadvantage of being favorable to the formation of fog and of low stratus clouds, especially in winter, and during prolonged dry spells in summer a ground haze, which interferes with reconnaissance work, is common. High pressure spells in summer are also apt to be times of active ascending diurnal currents; hence of "bumpy" conditions. The diurnal increase in wind velocity and the diurnal variation in wind direction are also best marked at such times.

Low pressures, on the other hand, are usually accompanied by general cloud sheets; by rain or snow; often by high winds, especially in winter. They thus bring conditions which may make flying difficult; ineffective; even impossible.

Addendum.—The following outline of a course in Meteorology suited to the needs of aviators is here given for the convenience of those who may be called upon to give instruction in this subject. It is a syllabus of the lectures given by the writer in the course in Aeronautical Engineering at the Massachusetts Institute of Technology.

[57] In England Capt. C. J. P. Cave has shown that different types of wind velocity distribution in the atmosphere prevail under different conditions. Thus, he has found cases when (1) the velocity remains steady even up to several thousand feet, (2) the velocity increases with height (usual condition), (3) the velocity decreases and then increases, (4) the velocity increases and then decreases.

Introductory.—Importance of a knowledge of Meteorology in aviation:

(a) general climate

(b) weather and weather forecasts:—military field meteorological services.

The Atmosphere.—Composition; height; "Troposphere" and "Stratosphere": general characteristics of each.

Temperatures in the Free Air.—Measurement of temperature: thermometers and thermometer scales; thermographs; "sounding the air;" vertical temperature gradients; temperatures at various heights; inversions; stable and unstable conditions in relation to flying.

Pressure.—Importance; comparison with water; decrease with altitude; physiological effects of diminished pressure; measurement: mercurial and aneroid barometers and barographs; use, errors, corrections; determination of altitudes by means of barometers; isobars; pressure gradients.

The Wind in Relation to Pressures at the Earth's Surface.—Wind direction: deflection of winds from gradient; earth's rotation and friction; cyclonic and anticyclonic wind systems; "Buys Ballot's Law;" isobaric types. Wind Velocity: general relation to gradient; Beaufort Scale and its equivalents in force and in velocity in miles an hour; Robinson and Dines anemometers; gustiness of wind.

Air Currents Above the Surface in Relation to Aviation: "Holes" in the air—(a) general air movements, essentially horizontal: atmospheric layers and waves; (b) local convectional currents, essentially vertical, due to thermal controls: causes and conditions; (c) effects of topography upon air movements, combining both horizontal and vertical elements, due to mechanical controls: effects of friction, topography, and character of surface; vertical and horizontal movements in general in relation to flight.

Clouds.—Importance in aviation; methods of determining cloud heights and velocities; cloud types and cloud classification; value as weather prognostics; special consideration of cloud types which are most critical in aviation; fog.

Weather Forecasting.—Explanation of daily weather map; observations of rainfall, humidity, cloudiness; principles of forecasting explained by reference to type maps, for United States and for Europe; general characteristics of cyclones and anticyclones; tracks; velocities of progression; thunderstorms; tornadoes; non-instrumental local forecasts; barometric tendency; veering and backing winds; changes in wind velocity; weather proverbs.

Forecasts of Wind Velocity and Direction Aloft.—Direct observation by means of pilot balloons, kites and cloud movements; inferences based on surface conditions and on general knowledge of upper air

currents; wind directions at various heights in cyclonic and anticyclonic systems in the United States and in Europe; "gradient wind;" diurnal variation in wind direction and velocity; changes due to progression of cyclones and anticyclones.

Favorable and Unfavorable Weather for Flying.—Wind, clouds, haze, etc.

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THE CIRCUMFERENCE OF GEOGRAPHY*

NEVIN M. FENNEMAN

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INTRODUCTION.—It is a peculiarity of geography to be always discussing and debating its own content—as though a society were to be organized for the sole purpose of finding out what the organization was for. This is not said by way of criticism; indeed this very paper is a continuation of the same discussion. The situation is, however, unique and can scarcely fail to be remarked by on-lookers from other sciences, who have no such doubts as to what their subjects are about.

The basis of this constant concern is not greed but *fear*. Geography wages no aggressive wars and seems to covet no new territory. In certain quarters it bristles with defense; but it is mainly concerned with purging its own house rather than spreading its borders. To rule out "what is not geography" would seem from the discussions to be much more important than to find and claim geography where it has been passing under other names. The constant apprehension is that by admitting alien subjects we shall sooner or later be absorbed by a foreign power and lose our identity.

It is probably unnecessary to point out that this is purely an American attitude. Geography of the European brand has no such concern for its own purity or fear of being absorbed. Scholarly geographic treatises from Europe may contain long lists of botanical names, or geological descriptions, or chapters which might be transferred bodily to monographs on economics or history.

To many American geographers this would seem like betraying their cause and selling their birthright. There is an implied dread that if geography accepts the work and uses the language of other sciences, geography itself will be dismembered and its remains be divided among its competitors. It is worth while to consider this possibility, and a rough plan is here submitted for a partition of geography's domain.

* Presidential Address delivered before the Association of American Geographers, Baltimore meeting, December, 1918.

Suppose geography were dead, what would be left?

Proposed Partition of Geography's Domain.—Geology might easily take over topography, including its genetic treatment, which is physiography—in fact, has never given it up. So also botany has never relinquished plant geography and ecology. Zoölogy does not

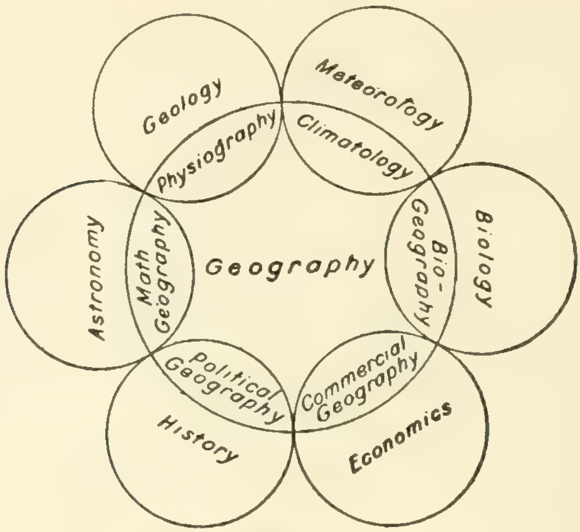

Fig 1—This diagram expresses the fundamental conception that sciences overlap and that each one of the specialized phases of geography belongs equally to some other science. Such a diagram will be helpful if not construed too strictly. In a loose way the central residual part of the circle may represent regional geography.

forget the distribution of animals. Agriculture is now so specialized and so firmly entrenched that crops and their distribution, and their relation to all manner of factors, are studied without concern for geography. Meteorology has official standing in all civilized countries and could take care of climatology if geography were bankrupt. Moreover, meteorology is commercially employed and so has the satisfaction of being good for something beside being merely good "to teach." So it is not afflicted with heart searchings regarding its own content. Mining is abundantly treated by geology and economics. The geographer only borrows from these, smooths out their details, and relates their results to something else. So economics deals with all other industries and with commerce, sometimes availing itself of the aid of chemistry and other sciences and always paying its respects to engineering.

A good part of what is termed political geography is covered also by history, and history would be more rational if it included still more. Political science, ethnography, etc., cultivate other parts of the geographical field and do it more exhaustively than does geography. Mathe-

matical geography is, of course, pure astronomy, except for cartography, which is straight mathematics.

Thus it seems that, with geography dead, all its tangible effects would be claimed by relatives and the estate could be settled up. To say the least, this is disconcerting. The case is not made better by the reflection that a large number of educated persons would see no reason for objecting to such a solution, provided only that geography were preserved for children up to the age when serious study should begin.

Dependence of Geography on Other Sciences for Its Material.—At this point, while geography is confessing its limitations, it may as well be owned that, outside the field of exploration, the geographer is mainly dependent on others for his data. Aside from mere location, direction, and distance, almost every fact that he employs belongs quite as much to some other science. In so far as that fact represents a class, the entire class of facts is much more apt to be known exhaustively by the other science than by geography. If the geographer speaks of soils, the agriculturist knows more; if he speaks of mines, the geologist knows more; if the reference be to manufacturing, the economist's knowledge is more thorough, or at least more exhaustive; if the subject is the people, the ethnographer, sociologist, or economist has first-hand knowledge, and the geographer is generally a borrower; and so through the list. With respect to all these data someone else is the original student, the "authority," and the geographer is merely "informed." How often is a geographer called in as an expert, and in what lines? This question is not intended to suggest a wholly negative answer, especially in view of the fact that three of our members are at present in Paris on the staff of the Peace Commission and nearly one-half of our members have been engaged in some expert capacity during the war. It does not follow, of course, that all these were engaged as geographers.

Concession has here been made freely because scholars outside of geography know these facts to be true, and there is nothing to be gained by claiming more than we can defend. If geography is not worth while despite these admissions, its business may as well be wound up.

Need of a Synthetic Areal Science.—Reverting now to our former figure of speech, what has geography to say of its proposed demise, the division of its tangible effects and the settling of the estate? The obvious question arises: Would the decedent stay dead? If he were to come to life again, the situation woul[illegible]rrassing as between him and his relatives. Assuming tha[illegible] each of the branches named above as contributing to geography does its task

well with respect to Russia, for instance, is there any likelihood that a craving would arise for a synthetic picture of the whole or a critical study of inter-relations? If so, who would satisfy this craving, and who could paint the picture, and what would be its value or standing among scholars?

To begin with, the first question answers itself. There is not one chance in a hundred that ten years would go by without a conscious craving, and an attempt to meet the craving, for a comprehensive view of the areal unit; and not one chance in a million that a century would elapse before such an interest would be the center of a new science. It matters no whit that all concrete data are already organized into other sciences, each more exhaustive and more critical with respect to its own data than the new science; it is absolutely certain that interest in the areal unit as such would clothe itself in appropriate form. It is the *areal relation,* after all, that makes geography.

To dwell on the kind of picture to be painted is not within our present purpose. In part it is a mere assembling of facts from diverse fields, facts joined together by the sole bond of a common locality. Whether we deride or apologize for this aggregation of facts, call it mere description, mere compilation, mere this or mere that (whatever it is, it is always "mere"), this humble task must still be performed before higher work is possible. Description bears the same relation to geography that narrative does to history. There can be no sound philosophy in either, based on faulty narrative or description.

But data thus assembled from diverse fields do not remain inert. They react on each other like chemicals to produce new compounds, that is, new truths. If the geographer knows less about soils and crops than the agriculturist, less of climate than the meteorologist, less of industry than the economist, less of society than the sociologist, he should still be supreme in this field of secondary compounds which cannot be formed by those who handle the data of one science only.

Value of "Scientific Trespass."—This point needs no elaboration here, but it is worth while recalling a passage from the presidential address of Dr. G. K. Gilbert before this association in this same city ten years ago. In explaining his choice of a subject, he announced himself as an advocate of the principle of "scientific trespass." "The specialist who forever stays at home and digs and delves within his private enclosure has all the advantages of intensive cultivation—except one; and the thing he misses is *cross-fertilization.* Trespass is one of the ways of securing cross-fertilization for his own crops, and of carrying cross-fertilization to the paddock he invades."[1] Gilbert

[1] *Science,* Vol. 29, p. 122.

might have added that the geographer is, or should be, the great insect that carries pollen from field to field.

It is not intended here to concede that geography does not concern itself at all in the first-hand search for data. Geographers have, for example, done much for topography. Light on land forms has been by far the leading contribution of American geography (though it is a question whether anyone has contributed to this subject who was not first trained as a geologist).

Regional Geography the Core of the Science.—Since geography *is to be*, it is quite right that physiography and climatology and the study of natural resources and even ecology should be of its family and bear its name, but the point here urged is that these are not the things which make geography *necessary* and *inevitable*. They may be necessary to it, but it is not necessary to them. All these might live with geography dead. All these and others belong to the regions of overlap, or ground common both to geography and to some other science, and, having two parents, would not be totally orphaned if one died; but the study of areas as before described belongs solely to geography and is, moreover, an only child. If these figures are somewhat mixed, it may be well to add in plain English that the one thing that is first, last, and always geography and nothing else, is the study of areas in their compositeness or complexity, that is *regional geography*

It is not to be implied for one brief moment that physiography and the other branches named are not geography. They all become so when directed toward a geographic purpose. But without the touchstone of areal studies, there is nothing to make physiography other than geology, ecology other than botany, the study of natural resources other than economics.

There is, then, in geography this central core which is pure geography and nothing else, but there is much beyond this core which is none the less geography, though it belongs also to overlapping sciences. Here belong physiography and climatology, mathematical and commercial geography. Still, *the seeds are in the core, and the core is regional geography*, and this is why the subject propagates itself and maintains a separate existence. Without regional geography there is no reason why geography should be treated as a separate branch.

This emphasis on areal relations instead of on the "elements" which enter into such relations is, of course, not new. It comes to much the same thing in practice as Ritter's "home of man" or Davis's "physical element and human element" or this and that man's "responses" or Keltie's "science of distributions" or Hettner's *"dingliche Erfüllung der Erdräume"* (material filling of the earth's surface). Nor is it necessary, for the purpose here in hand, to point out that every element

(topography, vegetation, climate, etc.) can be treated with reference to its distribution as well as with reference to its types. Such a treatment belongs to regional geography. It should, however, be noted that the study of the distribution of any one element by itself falls somewhat short of that *distinctive* geographic flavor which comes only when the various elements are studied in their inter-relations.

Cultivation of the Central Theme of Geography as a Safeguard Against Absorption by Other Sciences.—Let us now go back to the fear above alluded to, that our subject is going to be swallowed by something else. Why this constant dread? The situation at once suggests that we live too much on our borders and not enough in the center. If we dwell mainly in systematic physiography, why should not geology claim us as a vassal? If we live largely in commercial geography, we are in similar danger from economics; and why should it not be so? We can go round the circle with the same logic. A narrowly political geography of boundaries and capitals never had any reason for a separate existence apart from history.

If we are concerned for our independent existence no amount of fortifying our border will take the place of developing our domain. What we need is more and better studies of regions in their entirety, their compositeness, their complexity, their inter-relations of physical, economic, racial, historic, and other factors. No other science can swallow that and live.

Unnecessary Discrimination Against Geologic Terms.—An illustration of warring on the border instead of farming our domain is found in our curious boycott of terms from other sciences even when needed to make the truth clear. It is not permissible to say that the Cumberland Plateau is co-extensive with the strong "Carboniferous" rock (even where that is true) or that the High Plains (of Nebraska and Wyoming) end at the north with certain late "Tertiary" formations. It is permissible to say that the Cumberland Plateau is as broad as certain "resistant" rocks, but a term which would enable us to locate those rocks on the geologic map is taboo. True, the plateau border can be made out on very large-scale and awkward-to-handle topographic maps, but such maps at best are empirical, while the geologic map is interpretative. Since when has geography become so reactionary? Why must we secrete the geologic map as medieval priests secreted the Bible?

In the debates concerning this point there has been the most curious oversight of common usage. "Carboniferous" and its like are dubbed "geologic time names." Such they are indeed, sometimes, just as "Carboniferous" might be the name of a man or a horse or a brand of

shoe polish—all as irrelevant as geologic time—but the term also designates a body of material (in this case a system of strata) and, more important still, on the geologic map its stands for an *area*. "Triassic" indeed connotes geologic time, but the same word designates certain areas on the geologic map of the eastern United States. "Portage" is not only a Devonian epoch but a belt on the geologic map of western New York, a belt that must be spoken of and cannot be designated with equal clearness under any other name. In this manner, much use is properly made of geologic terms, not because they are names of epochs but because they are names of areas that force themselves on our notice by certain peculiarities, thus leading to rational explanations. For three-fourths of the United States the geologic map is beyond comparison the one most valuable map for interpreting topographic contrasts between adjacent areas. Why must the words printed on it be classed as dangerous? The answer is: Geography is in danger of being swallowed, and self-preservation is nature's first law.

But "Cumberland Plateau" is a geographic term. How can the geologist say with impunity that the Carboniferous rocks are co-extensive with the Cumberland Plateau? Is not the danger mutual? Is his science not in danger of being swallowed by geography? The answer is: He is not afraid on that borderland where sciences overlap, because his own peculiar domain, which is not overlapped by geography or anything else, is too large and too well cultivated to admit of such fears. Our own safety lies in the same policy.

In our efforts toward self-preservation through purity, we have classed scientific terms as clean and unclean. The latter, such as Archean, Mesozoic, etc., cannot be touched without defilement. So we have built up a whole ceremonial by which we hope to be saved; but not so is salvation found. Its price to geography is no less than the diligent cultivating of its own peculiar field, the doing of something which the world needs and which no other science can do.

Animals have more than one way of evading the jaws of their competitors. The turtle is encased and puts up a good defense but is weak on the offensive. It is the same with the oyster. Others, like the squash bug, owe their safety to a peculiar flavor or odor. Still others specialize in modes of escape. But all such special provision belongs to the weak rather than to the strong. If geography will cultivate its own strength like the large mammals, it will not be necessary for it to encase itself like the oyster or cultivate the peculiar flavor of the squash bug to avoid being eaten.

In so far as there are frontiers between the sciences, let us have them ungarrisoned and let us have free trade. Let there be among sciences the same struggle for existence and law of survival that Darwin found

among species. Then every field of study that answers to an intellectual need will have due recognition.

THE SEVERAL SCIENCES DESIGNATED BY THEIR CENTERS, NOT BY THEIR CIRCUMFERENCES.—The subject announced for this brief address was "The Circumference of Geography." Presumably enough has been said to show that a science cannot be defined by its circumference. We may designate the center, and that should be enough. Everyone knows what botany is so long as we stay near the center, but where is its farthest limit? Far out in chemistry and medicine and geology, to say the least. And where is the limit of chemistry? Nowhere. Yet chemistry is not hard to define if it be designated by its center instead of by trying to draw its circumference. So the center of geography is the study of *areas*, generally, of course, in relation to man, for human habitation affords the most frequent utilitarian reason for such study and is also the center of the greatest intellectual interest; but the comprehensive study of an uninhabitable region would still be geography.

It is not only the right but the duty of every science to develop all parts of its domain, but it is none the less true of all, as of geography, that their right to separate existence depends on their cultivation of that part of their field which is not overlapped by others. Let there be no misunderstanding; there is no intention of assigning more dignity to one part of the field than to another or of asking any man to turn aside from that which interests him to something else. There is no more inherent worth in a center than in a border. But some of us have a philosophic interest in viewing relationships, and in asking why the whole range of knowledge has grouped itself around certain centers, and what it is that keeps those centers, which have received names, somewhat permanent, and what the advantage is in grouping knowledge around one center rather than another.

Moreover, all of us have a very practical interest in seeing that our own work should not suffer by isolation. We all want our own work to have the advantage of connections, and it is greatly to our interest that somebody should cultivate certain central fields even though most of us work on the borders. The logic of events, if no other logic, has brought together in this association a group of men of rather diverse interests. We are disposed to think that this is not a mere chance but that something fundamental underlies our union. Much that interests the individual does not concern the whole; but we feel more or less intelligently that there is profit in this intercourse and we want the relation to be closer. If there is a class of studies that will make our separate fields more important and more interesting to others and enable us to profit

more by our association, we want to know what that class is and to encourage it.

Beside those who are, first and last, geographers, our association contains geologists, topographers, geodesists, meteorologists, ecologists, zoölogists, geophysicists, historians, and economists. The list is not intended to be complete. We have joined ourselves together evidently expecting to find a common interest. Where is the common ground on which such diversity can meet? Interest in places, areas, regions is the common bond.

This quasi-philosophical study of relationships is therefore important to those whose privilege it is to direct research or to organize education. If men in such position decide with eyes open that physiography and commercial geography and anthropogeography and the rest should not be merely geology, economics, ethnography, etc., they must act accordingly. The character of these subjects cannot be controlled by ceremonial law. The effective way is to set in the midst of them a great light, the light which comes alone from the comprehensive, rational, systematic study of regions.

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CLIMATIC AND GEOGRAPHIC INFLUENCES ON ANCIENT MEDITERRANEAN FORESTS AND THE LUMBER TRADE

ELLEN CHURCHILL SEMPLE

The Mediterranean Basin is a climatic unit. It is a region of winter rains and summer drought, of warm summers and mild winters. The summer drought increases in length and intensity from north to south. The annual precipitation throughout the region as a whole is relatively scant, but it varies greatly from one district to another. It declines from north to south, from highland to lowland, and from the west side of peninsulas and islands to the east side. It ranges from 10 inches at Alexandria to 20 inches at sea level in Crete, 52 inches in Corfu, and over 60 inches on the Alps near Trieste; from 8 inches at Cairo to 36 inches in the mountainous littoral of Algiers; from 16 inches at Athens on the eastern side of Hellas to 40 inches in Cephalonia only 170 miles away on the western side, where the land lies exposed to the rain-bearing winds.* It is not the amount of the rainfall, however, but its seasonal distribution which characterizes the Mediterranean climate.[1]

This climate is due to the location of the Mediterranean Basin between two regions of sharply contrasted precipitation—between the tradewind or desert tract of Africa and the belt of the prevailing westerly winds, which all year round bring rain from the Atlantic to northern and middle Europe. The Mediterranean Basin occupies a transition zone between the two, and partakes in turn of the climatic character of each, according to the season of the year. In summer it approximates the arid conditions of the Sahara; in winter it reproduces the stormy skies and frequent rains of France and Germany; but the aridity is greatly attenuated along the northern rim of the Basin, and the rainy season is similarly attenuated along the southern rim, except

* NOTE.—After reviewing the evidence, the author has reached the conclusion that no appreciable change of climate has occurred in the Mediterranean region in historical times. Therefore recent rainfall statistics are cited.

1 For general character of the Mediterranean climate and vegetation today, see
A. Philippson, *Das Mittelmeergebiet*, Leipzig, 1907.
Theobald Fischer, *Mittelmeerbilder*, Leipzig, 1908.
Naumann and Partsch, *Physikalische Geographie Griechenlands*, Breslau, 1885.
Wilhelm, Deecke, Italy, Trans. from the German. London.
R. Fitzner, *Niederschlag und Bewölkung in Kleinasien, Peterm. Georg. Mitt. Ergänzungsheft*, vol. xxx, No. 140. Gotha, 1903.
F. Trzebitsky, *Niederschlagsvertheilung auf. der Sudost Europäischen Halbinsel, Peterm. Geog. Mitt.*, vol. 55, Gotha, 1909.
M. Newbegin, The Modern Geography, New York and London, 1911.

where the high Atlas Mountains make a local area of heavy precipitation.

The Mediterranean Basin as a whole is distinguished not only by a common type of climate, but by a type of vegetation whose common physiognomy reflects the prevailing climatic conditions. Thus the ancients described it, and thus we find it today. Trees, shrubs, herbs and grasses in their structure and life course show a close adaptation to their environment. Many of them which were immigrants from northern Europe and central Africa became modified to suit Mediterranean conditions of climate and soil.

Like the Mediterranean climate, Mediterranean vegetation shows a series of graduated transition forms. On the north it merges into the plant life of middle Europe with its dense forests, abundant deciduous trees, juicy grasses and weeds, which are amply watered by the rains all year round, grow during the summer heat, and rest during the winter cold. On the south it gradually passes over into steppe and desert vegetation adapted to arid conditions—a sparse growth of thorny or spiny shrubs armed to resist the prevailing drought and to conserve the meager store of water which they get during the winter showers. Mingled with these shrubs is an equally sparse growth of grasses and herbs which spring up in moister districts after the winter rains, hasten through their few weeks of life, and die down under the parching summer heat. In desert and steppe alike the growth is thin; each plant stands apart from its fellows in an effort to monopolize a maximum space for its thirsty roots.

In type and in location the Mediterranean vegetation stands between these two contrasted groups of plant life. It knows neither the blessing of the all-year rainfall, nor the curse of Africa's aridity, but it has a taste of the latter in the long summer drought, while in the winter rains it gets the abundant moisture of the north, combined with sufficient warmth to keep its life processes going. In winter and spring, therefore, it has its period of growth, and in summer its period of rest. To these natural conditions it has adapted itself, and under them it has spread over Mediterranean lands as far as Mediterranean climatic influences penetrate. It finds its limit not far from the sea itself, because this body of water is the main reservoir of the winter moisture. At a relatively short distance back from the coast the typical Mediterranean vegetation gives place to steppe vegetation, as in Africa, central Spain and Asia Minor. In the mountains, where the winters are colder and the summers moister, it merges into a highland vegetation which closely resembles that of middle Europe, and in higher altitudes it passes over into Alpine types. The genuine Mediterranean vegetation, therefore, belongs to the lowlands and to the vicinity of the coasts. It is most typical in the middle zone of rainless summers found

in southern Spain and Italy, in Greece and Palestine. Farther south it is gradually transformed into the plant life of the steppes; farther north it merges into that of middle Europe.

In this broad transition zone, cereals and other grasses, having superficial roots and hence depending on the surface moisture in the soil, sprout during the warm rains of autumn, grow slowly during the winter, rapidly during spring, and reach maturity in early summer. After this they dry up in the drought and heat. Tuberous, bulbous and annual plants, likewise dependent upon surface moisture, are reawakened to life by the first warmth of spring, grow and blossom and seed while the soil is still damp, thus completing their life processes before the summer drought. To these groups of plants belong the chief crops of cereals and vegetables raised by Mediterranean agriculture. Therefore, from time immemorial winter has been the period of tillage in Mediterranean lands for all native crops, spring or early summer the harvest time, and middle or late summer a season of comparative leisure for farm labor.

Plants and trees that weather the long summer are equipped to resist drought. Many have elaborate root systems, which enable them to gather in moisture from a large area and especially from the deeper layers of soil. Their leaves are commonly narrow, often needle-shaped, so that they present the least possible surface to the sun. Some take the form of spines and thorns, which indicate approach to desert conditions. The leaves have a dark green or gray color, with a polished or resinous surface above and a silvery coating of hairs beneath. All these are nature's devices to diminish evaporation and thus conserve moisture in the plants. Many species of trees are dwarfed and gnarled, with stocky trunks and low branches hugging the ground, where rest the moister strata of air; for the higher the trees, the more they are exposed to the drying action of the winds. Others that grow tall, like the cypress, spring up into a slender spire of dark green, presenting little surface to the sun. Trees and shrubs at sea level are evergreen or nearly so. Even deciduous trees lose their leaves for only a brief space, because they need both the winter rain and summer heat to complete their life functions.

Mediterranean forests reflect the vicissitudes of their life conditions embodied in the long summer drought. The dense continuous forests which stretch across middle and northern Europe under the influence of an ample and well distributed rainfall reach their southern limit just within the northern border of the Mediterranean Basin. Beyond this margin, life conditions fluctuate or fail; the summer water supply is inadequate. Each tree, therefore, appropriates a large area with its spreading roots in order to get sufficient moisture. Consequently Mediterranean forests are usually sparse woodlands or savannahs, open

plantations into which the light penetrates. Genuine forests of the European stamp are found only on the northern rim of the Basin and on high mountains which are able to condense moisture from the summer clouds. They are ample on the Pyrenees, Alps, northern Apennines, the Macedonian highlands, and the mountain coasts of the Black Sea. In southern districts they occur as islands of green foliage on lofty mountains, like the peaks of Sicily, Arcadia, Crete and Cyprus, and especially on westward facing slopes like Mount Amanus and Lebanon. Palestine, even in very early times, knew no forests except the pine woods of Mount Hermon, firs and cedars of Lebanon, and the oak groves of Bashan or Gilead. Scarcity of timber made tall trees conspicuous landmarks and even objects of worship. In the southern lowlands forests degenerate into poor scrub growth, or shrink to detached groups of trees about a spring pool, or contract to a narrow ribbon of foliage along a wadi bed, or are replaced by irrigated plantations of domestic trees as in Egypt, or they succumb to the power of the desert.

The mountains of the Mediterranean Basin show climatic zones of altitude with their appropriate tree growth. On lower slopes the forests consist of mountain pine and evergreen oaks, up to an altitude of 2,000 or 3,000 feet. Above that height grow deciduous trees, like the oak, elm, chestnut and beech; at this elevation they get enough rain to do their life work in summer, when they also get more heat than the winter affords. The chestnut grows at altitudes from 2,000 to 5,000 feet according to the latitude; above it is the beech, and higher still are firs and cedars. Deciduous trees increase in abundance from lower to higher altitudes and from south to north. This is also the ancient distribution described by Theophrastus and Pliny. Theophrastus found the water-loving plane-trees lining the banks of the perennial rivers of Greece;[2] and today the modern traveler, tramping through the Vale of Tempe along the swift-flowing Peneus, enjoys their grateful shade.

The dense forests that covered the mountains along the northern rim of the Mediterranean Basin undoubtedly intensified their barrier nature in ancient times, and helped to discourage invasion by the pastoral nomads of the Eurasian grasslands. The wooded heights of the Caucasus, Balkans and Carpathians probably deflected many a migration away from Asia Minor and Greece, and turned it westward over the open plains of the lower and middle Danube towards Italy and Gaul. But these thick border forests once passed, the early peoples who pushed their way into Mediterranean lands found easy going for themselves and their wide-horned cattle through the open woodlands of the valleys and coastal plains. When they halted to make permanent settlements,

[2] Theophrastus, *De Historia Plantarum*, Bk. iv, ch. v, 6.

they had only thin forests to clear before sowing their crops. This consideration must have been an important factor in territorial expansion in the days when stone and bronze axes were the only weapons of attack upon hardwood trees. Indeed, history gives us hints that the primeval forests of Cyprus[3] and Corsica[4] were a deterrent to the earliest Greek and Roman settlements on these islands.

The relative paucity of trees in the lowlands and coastal strips, just where population settled thickest, resulted in a rapid denudation of the forests about the ancient cities and towns. This in turn gave rise to early importation of various woods from better timbered regions to deforested districts like Attica, and to forestless areas like Philistia and Egypt, whose local species of trees yielded little or no lumber. The result was the very early development of the lumber trade. This supplied the demand for fuel, building materials, cabinet woods and ship timber; the latter included special kinds of lumber for keel, hull, decking, masts and oars.

Owing to the diminution of rainfall from north to south, from west to east, and from highland to lowland, these were exactly the directions in which the chief lumber traffic moved. Exceptions occurred mainly where choice woods from a limited area of production gradually acquired wide use, as in the case of the tall pines of the Caucasus and the unsurpassed cedars of Lebanon. The ebony and teak imported from India over the eastern rim of the Basin met a demand in all the capital cities.

The wide distribution of mountains within and around the Mediterranean Basin made the highlands the predominant source of lumber from the earliest historical times. In the Iliad, Achilles sent mules and wood cutters to Mount Ida to bring oak for the funeral pyre of Patroclus down to the Trojan plain. Later Priam got the fuel for the pyre of Hector from the same source.[5] Mount Pelion furnished the shaft of ash for the spear of Achilles.[6] Sarpedon fell in battle "as falls an oak or silver poplar or a slim pine tree that on the hills the shipwrights fell with whetted axes, to be timber for ship-building." The roar of conflict about the dead Sarpedon was "as the din of woodcutters in the glades of the mountains."[7]

The scant rainfall of the Eastern Basin except on the highlands emphasized the value of the mountain forests. Therefore, the ancients had a sharp eye for this source of their lumber supply. Homer speaks

[3] Strabo, Bk. xiv, ch. vi, 5.

[4] Theophrastus, *Hist. Plant.*, Bk. v, ch. viii, 2.

[5] Iliad, xxiii, 118-121; xxiv, 663.

[6] Iliad, xix, 390-392.

[7] Iliad, xvi, 482-384; 634-636.

of "the topmost crest of wooded Samothrace;"[8] Hesiod knew "where oaks the mountain dells imbranch on high,"[9] and Aristophanes "the wood-crowned summits of the lofty mountains."[10] Theophrastus, discussing the tree life of the Eastern Basin, alludes to the woodlands of the plains, but discourses at length on the important forests of Lebanon and Taurus mountains, Mt. Tmolus of Lydia, the Mysian Olympus, Mt. Odynnos of Lesbos, Phrygian Ida, Mt. Cytorus and the other Pontic ranges of Asia Minor, Haemus and other Thracian mountains, the Macedonian highlands, Thessalian Olympus, the high wooded ridges of Magnesia, certain ranges of northern Hellas, Mt. Parnassus and certain peaks of Euboea, Mt. Cyllene and the Arcadian highlands in general, Mt. Ida of Crete and the Leuca ranges in the western part of that island.[11] He repeatedly emphasized the general superiority of mountain woods for timber purposes, even where a given species of tree grew alike in highland and lowland and reached a taller growth in the more fertile soil of the plain. In the case of mountain trees, he discriminated in favor of forests covering the high level stretches or terraces of plateau and range, as against the stunted timber of the lofty summits.[12] It is a striking fact also that Theophrastus constantly cites the classification, nomenclature and description of trees current among the people of Phrygian Ida, Macedonia and Arcadia.[13] All these were mountaineers, backward in the culture prized by the Attic Greeks, but evidently recognized authorities in everything pertaining to forestry and lumbering.

Pliny, who enumerated the lumber resources of the whole Mediterranean Basin, also noted that the quality of trees depended upon their place of growth. According to him, the best Italian timber came from the Alps and Apennines, the best Gallic woods from the Jura and Vogesus ranges. The Gallic lumber was doubtless floated down the Rhone and Saone to the Mediterranean. Other well-known lumber regions which he enumerated were all mountainous—Corsica, the Pyrennees, Bithynia, Pontus, Macedonia, Arcadia, Crete, the Lebanon district of Syria, and the coast ranges of Roman Africa which yielded the famous Atlas cedars.[14]

As the mountains of the Mediterranean Basin rise almost everywhere directly from the sea, the logs were floated down the drainage

[8] Iliad, xiii, 13.

[9] Hesiod, Work and Days, ii, 203.

[10] Aristophanes, Clouds, 281.

[11] Theophrastus, *Hist. Plant.* Bk. iii, ch. ii, 5, 6; ch. iii, 2-4; ch. v, 1; ch. ix, 5; ch. x, 6; ch. xv, 5; xviii, 3-6, 13. Bk. iv, ch. 1, 2-3; ch. v. 2-7.

[12] Ibid. Bk. iii, ch. iii, 2.

[13] Ibid. Books iii, iv, and ix, *passim.*

[14] Pliny, *Historia Naturalis,* Bk. xvi, chs. 15, 16, 18, 39. Bk. xiii, chs. 15, 16.

streams in flood time to the nearest harbor, whence they were exported. Ancient writers frequently emphasize the accessibility of the timber supply to the coasts. Tyre and Sidon were great lumber ports from early times. When King Hiram made a contract with Solomon to furnish the wood for the new temple of Jerusalem, he sent his expert lumbermen up into the Lebanon ranges and collected the cedar and pine logs (translated "fir" in the Bible) at Tyre. There he made them into rafts and had them towed down the coast to Joppa.[15] Both Tyre and Sidon furnished cedars for the rebuilding of the Jewish temple after the Babylonish captivity, and transported them by sea to Joppa.[16] The various woods of Mount Ida in Phrygia reached Mediterranean trade through the port of Aspaneus, located near the head of the Adramyttene Gulf.[17] Forests which did not command easy transportation to the coast long escaped the woodman's axe, or supplied merely local needs unless general scarcity of timber intensified the demand. After the Macedonian conquest of Cyprus, the Greek kings of the island began to conserve the valuable cedars of their mountains when it proved to be a losing business to pay the freight charges from the interior to the coast.[18]

The Mediterranean lumber trade was more active in the Eastern Basin than in the western, because of the very irregular distribution of forests and the meagre tree growth around the Levantine and Aegean seaboard. The chief importers of lumber were the populous maritime cities surrounding the Aegean, who wanted it for their big merchant marine and various domestic purposes. They used the woods of coniferous trees, like fir, various pines, juniper and cedar primarily for ships,[19] but employed them also extensively in the construction of buildings. Cypress, laurel, box, olive, poplar, maple, wild fig, larch, chestnut, walnut, beech, oak, elm, ash, mulberry, plane and holly were used for carpentry and cabinet work.[20] Keels of ships were occasionally reinforced with oak for greater strength,[21] or with beech when they had to be hauled.[22] The modern is often amazed at the ancient use of woods for manufacturing or building purposes which are now regarded fit only for fuel or wood pulp.

Many woods were widely distributed over the Mediterranean Basin, like the box, olive, fig, various oaks and conifers. Some were found chiefly in southern lands, like the cypress in Cyrene, Crete, Rhodes

[15] II Chronicles, ii, 16. I Kings, v, 5-12.

[16] Ezra, iii, 7.

[17] Strabo, Bk. xiii, ch. i, 51.

[18] Theophrastus, *Hist. Plant.* Bk. v, ch. viii, 1.

[19] Ibid. Bk. iv, ch. v. Bk. v, ch. 7-8; ch. vii, 1-3, 5; ch. viii, 1-2.

[20] Ibid. Bk. v, ch. iii, 1-7; ch. iv, 1-2; ch. vii, 4-8.

[21] Ibid. Bk. v, ch. iv, 3; ch. vii, 6.

[22] Ibid. Bk. iii, ch. x, 1. Bk. v, ch. vii, 2.

and Lycia,[23] and the palm in the desert belts. Those which supplied the best and most abundant lumber grew on the western slopes of high mountains or in the northern zone of the Mediterranean Basin.

The whole African coast of the Eastern Basin was practically lacking in timber, owing to the semi-desert conditions. The Egyptians cut short planks three feet long from the local acacia trees for constructing their river transport boats,[24] and they utilized the wood of the olive, sycamore (Ficus Sycamorus), *balanos* and doum-palm for cabinet and carpentry work in lieu of anything better.[25] The paucity of their wood supply is indicated by their skiffs made of bundles of papyrus reeds, after the manner of the balsa boats of Lake Titicaca in Peru, and by the use of the papyrus root as fuel. The highland oasis of Cyrenaica had olive, lotus and cypress trees, of which only the last could be used primarily for lumber.[26] The thuya or thyon tree (Callistris quadravalvis), a juniper nearly related to the cypress, grew abundantly in Cyrenaica and the oasis of Ammon in the fourth century B. C. It furnished material for roofs in very ancient times, but as the wood was fragrant and proof against decay, it was valuable for cabinet work.[27] It entered into the trade of the Eastern Mediterranean by way of Crete or Egypt. Homer makes Calypso burn it with cedar and larch to perfume her grotto, and the Book of Revelations, written in the latter part of the first century A. D., alludes to it as a choice wood of commerce.[28]

The absence of forests and paucity of timber trees made these regions of lowland north Africa importers of lumber. The same conditions held in Palestine and the low Philistian coast. Their nearest source of supply lay in the cedar forests of Lebanon, the pine woods of Mount Amanus, which forms a northern extension of the Lebanon range, and the wooded heights of Cyprus. Hence these forested districts were national possessions envied by all the countries around the Levantine Sea. The timber of Mount Amanus and Lebanon occasioned the repeated conquest of these ranges by Egypt in the south and especially by Babylonia in the arid southeast, which had imported thence building material for its temples since 3000 B. C. or earlier.[29] It supplied wood for the Phoenician export trade in cedar and pine logs to Palestine and Egypt,[30] and for countless Phoenician fleets. Tyre secured

23 Ibid. Bk. iii, ch. i, 6; ch. ii, 6. Bk. iv, ch. iii, 1; ch. v, 2.

24 Herodotus, ii, 96.

25 Theophrastus, *Hist. Plant.* Bk. iv, ch. ii, 2, 6-9.

26 Ibid. Bk. iv, ch. viii, 4.

27 Ibid. Bk. v, ch. ii. 7.

28 Odyssey, v. 60. Revelations, xviii, 12.

29 F. Hommel, *Geschichte von Babylonien und Assyrien*, pp. 328-330. Berlin, 1885.

30 J. Breasted, History of Egypt, pp. 95, 114-115, 127. New York, 1909.

ship timber also from the coniferous forests of Mount Hermon, whose great height (8,702 feet or 2,653 meters) insured summer showers, and it imported oak for oars from Bashan.[31]

The mountain forests of Cyprus, together with the copper mines, doubtless furnished the motive for the Phoenician conquest of the island in the eleventh century B. C. Even at this early date the necessity of conserving the Lebanon timber may have become apparent, since the pine groves of Amanus had long before this been seriously invaded. Forests renewed themselves with difficulty under the climatic conditions of the Eastern Mediterranean. For centuries the Cyprian ranges furnished excellent cedar for ship-building; the Greek kings after the Macedonian conquest began to conserve the forests, which were evidently declining in extent and retreating from the shore.[32] Theophrastus states that in his time (313 B. C.) the Syrians and Phoenicians made their triremes of cedar because they had no fir and little pine timber, but that the Cypriots generally preferred Aleppo pine for this purpose because it grew abundantly on the island and was superior to their other woods.[33] Strabo, on the authority of Erastosthenes, states that the forests of the Cyprian plain were once so dense that they formed an obstacle to tillage; that though they were invaded for fuel to smelt the copper and silver from the local mines, and for timber to build whole fleets of ships, nevertheless, consumption did not keep pace with the growth of the forests until, by legal enactment, the act of clearing the land was made to convey title to it.[34] So dense a mantle of trees would indicate a heavier rainfall in Cyprus than the meager 15 inches (37 centimeters) recorded in recent decades. Erastosthenes' account, however, may be based upon traditions of the Bronze Age, when the people of the island had imperfect tools for clearing even their woodlands, and moreover, devoted their energies to mining rather than to agriculture. Yet even in Strabo's time a forest covered the western promontory of Acamas, which was exposed to rain-bearing winds.[35]

The high Taurus Mountains, which wall in the coast of Cilicia Trachea, Pamphylia and Lycia in Asia Minor, get today from 30 to 40 inches of rain (75 to 100 centimeters) from the southwestern storms. The Pisidian Taurus range, back of the Gulf of Adalia, abounded in forests in ancient times. It was drained by the Eurymedon and Melas rivers, which were apparently used as log streams to float lumber down to the coast; because between them lay the seaport

31 Ezekiel, xxvii, 5, 6.

32 Theophrastus, *Hist. Plant.* Bk. v, ch. viii, 1.

33 Ibid. Bk. v, ch. vii, 1.

34 Strabo, Bk. xiv. ch. vi, 5.

35 Strabo, Bk. xiv, ch. vi, 2.

of Side, where the Cilician pirates placed their shipyards.[36] The Cilician and Lycian Taurus produced fine cedars,[37] which the pirates used for their swift-sailing boats. The Persians also utilized these timber supplies in the shipyards which they maintained on the Cilician coast. There Artaxerxes in 460 B. C. built three hundred triremes for an attack on Egypt.[38]

After the Roman conquest the chief lumber port of this coast was Hamaxia,[39] near the site of modern Alaja. Just behind this town the Taurus Mountains rise to 10,266 feet (3,130 meters) and therefore get ample precipitation for forests, though the seaboard receives less than 20 inches. All this region was comparatively near Egypt and desirable to her for its timber. Hence that country, whose palm trees yielded poor lumber and whose irrigated fruit trees were too valuable for that purpose, maintained sovereignty over all or part of this forested mountain coast for nearly three hundred years after the break-up of Alexander's empire (323 B. C.). In 300 B. C. the Ptolemies owned Cyprus and the whole southern coast of Asia Minor from Rhodes and Lycia to Issus, but by 218 B. C. their possessions had shrunk to Cilicia Trachea and Cyprus.[40] These were retained till 67 B. C. and 58 B. C., respectively, when they were conquered by Rome; but later Mark Anthony assigned Hamaxia and the neighboring coast of Cilicia Trachea to Cleopatra to furnish wood for the Egyptian fleet.[41] In the thirteenth century Hamaxia had a successor in the port of Alaya, where the Seljuk Turks had shipyards for their navy.[42] So the Cilician forests persisted.

It was especially the northern mountains of the Mediterranean Basin, with their heavier rainfall and denser forests, which yielded the most ample and varied supply of timber, and which, therefore, furnished the chief cargoes for the lumber fleets of ancient times. These cargoes included other ship supplies besides woods, namely, pitch for caulking the seams of vessels, and wax for the encaustic painting of the hulls to make them impervious to water. It is a significant fact that wax and honey invariably figure as forest products in ancient Mediterranean trade, doubtless because numerous flowering trees and shrubs like myrtle, laurel, oleander, tamarisk, hawthorn, lime or linden, wild apple and pear mingled with other forest growth

[36] Strabo, Bk. xii, ch. vii, 3. Bk. xiv, ch. iii, 2.

[37] Theophrastus, *Hist. Plant.* Bk. iii, ch. ii, 6. Pliny, *Hist. Nat.* xvi, 32.

[38] Diodorus Siculus, Bk. xi, chs. 60, 75, 77.

[39] Strabo, Bk. xiv, ch. v, 3.

[40] E. A. Freeman, Historical Geography of Europe, Atlas, maps vi, viii, ix. London, 1882.

[41] Strabo, Bk. xiv, ch. v, 3.

[42] Guy Le Strange, Lands of the Eastern Caliphates, p. 142. Cambridge, 1905.

and provided honey pastures for the bees. The rainy slopes of the Caucasus Mountains overlooking the Euxine yielded various timbers, especially those suitable for ship-building, besides wax and pitch in great abundance. These forest products were conveyed down the River Phasis to Colchis, whence they were exported.[43] They equipped the navies of Mithridates. Pontic pines, famous for ships, besides other woods used by builders and wheelwrights, were imported into Italy from the Caucasus forests during the last century of the Roman Republic.[44]

Along the northern shore of Asia Minor, from Colchis to Heraclea Pontica and Calpe[45] in Bithynia, the high Pontic ranges facing the Euxine winds were mantled with forests of excellent ship timber, besides oak, elm, chestnut, ash, maple and a superior variety of box. These woods could be easily conveyed away, Strabo tells us. They entered the Mediterranean trade through the ports of Cerasus or Pharnacea, Amisus, Synope and Amastris.[46] The walnut wood exported from Synope was a fine variety used for making table tops. Box trees grew in such perfection and abundance on the Cytorus range[47] in the coastal belt of Paphlagonia that they became proverbial and gave rise to the saying "carrying boxwood to Cytorus," equivalent to the English "carrying coals to Newcastle." The box yielded a very hard close-grained wood, almost proof against decay, used for the manufacture of sacred images, carpenters' tools, flutes and combs.[48] It was evidently imported into Italy for these purposes, for its fame is sung by Vergil, Catullus and Ovid, who always specify the Cytorian or Phrygian variety of box.[49]

In western Bithynia the mountains decrease in height, the rainfall of the Asia Minor coast declines to 28 inches (700 mm.), but the summer showers suffice for the forests. Near the Propontis, the Mysian Olympus rises to the height of 8,300 feet in the face of the Pontic winds, and receives enough precipitation (over 32 inches or 800 mm.)[50] for large, diversified forests.[51] In ancient times its export

43 Strabo, Bk. xi, ch. ii, 15-18.

44 Vergil, Georgic II, 440-445, Horace *Carmina*, I, 14, 11.

45 Xenophon, Anabasis, Bk. vi, ch. iv, 4, 5.

46 Theophrastus, *Hist. Plant.* Bk. iv, ch. v, 3, 5. Bk. v, ch. vii, 3. Strabo, Bk. xii, ch. iii, 10.

47 Pliny, *Hist. Nat.*, Bk. xvi, 16. Theophrastus, *Hist. Plant.*, Bk. iii, ch. xv, 5.

48 Theophrastus, *Hist. Plant.*, Bk. i, ch. v, 4, 5. Bk. v, ch. iii, 1, 7; ch. iv, 1, 2; ch. viii, 8.

49 Catullus, iv, 3. Vergil, Georgic II, 438. Ovid, Metamorphoses, iv, 311.

50 R. Fitzner, *Niederschlag und Bewölkung in Kleinasien*, pp. 78-80, rain fall map, p. 91. *Pet. Geog. Mitt, Ergänzungsheft*, vol. xxx, No. 140. Gotha, 1902.

51 Theophratus, *Hist. Plant.*, Bk. iii, ch. ii, 5. Bk. iv, ch. v, 3. Strabo, Bk. xii, ch. viii, 3, 8.

timber was floated down the Rhyndacus River to the sea,[52] and probably marketed through the Milesian port of Cyzicus. Mysian Olympus and Phrygian Ida furnished to the Aegean world varied and abundant timber, but little that was suitable for ship-building, according to Theophrastus.[53] The fir and pine forests of these ranges were probably approaching exhaustion in his time, 313 B. C. Mt. Ida's proximity to the fertile Trojan plain and the nine successive cities on the site of Ilium would suggest long exploitation of its best lumber. The process went on as late as 424 B. C. after the Athenian conquest of Lesbos, when refugees from the island occupied Antandrus on the mainland near by, and planned to build a fleet from the forests of Mt. Ida, for the purpose of harassing Lesbos and the neighboring coast cities of the Athenian league.[54]

The Aegean front of Asia Minor receives an average rainfall of 25 inches in the lowlands (Smyrna 26 inches or 650 mm.). This is scant allowance for forests, especially in view of the almost rainless summers. The whole region, however, from the Troad to Caria and Rhodes is crossed by numerous short mountain ranges in close proximity to the sea; their peaks, rising from 3,500 to 4,100 feet and receiving about 30 inches or 750 mm. of rain,[55] doubtless offered in ancient times sufficient timber for the needs of the early Phoenician and Greek colonies along this coast. Forested promontories and island peaks, like Mimas (3,803 feet or 1,190 meters), Mycale (4,150 feet or 1,265 meters), Mt. Atabyrius in Rhodes (4,067 feet or 1,240 meters) and Mt. Pelinnaeus in Chios (4,147 feet or 1,264 meters), were probably one attraction to settlers who sought the deep-running inlets for their new homes. The ranges were neither long nor very high, however, and had evidently lost much of their forest covering by the Christian Era. Theophrastus mentions only the woods of the Phrygian Mountains, which lie farthest north, and those of the Tmolus Mountains in Lydia, which, however, yielded no ship timber.[56] In Strabo's time, the bold sea-washed ridges of Mycale and Mimas were still well forested and harbored abundant game, while the hill country of Ortygia near Ephesus had woods of various trees, especially cypress groves.[57] The latter doubtless furnished the famous doors of the temple of Diana, but the cedar planks for its roof[58] were undoubtedly imported from Crete, Lycia, Phoenicia or Cyprus. The early exhaus-

52 Theophrastus *Hist. Plant.*, Bk. v, ch. iii, 1.

53 Ibid. Bk. iv, ch. ii, 5.

54 Thucydides, iv, 52.

55 R. Fitzner, *opus cit.* rainfall map, p. 91.

56 Theophrastus, *Hist. Plant.* Bk. iv, ch. v, 3, 4.

57 Strabo, Bk. xiv, ch. i, 12, 20, 33.

58 Vitruvius, *De Architectura*, Bk. ii, ch. ix, 13. Pliny, *Hist. Nat.*, xvi, 79.

tion of the local supply of ship timber forced the big trading cities of this coast to search for it abroad. Miletus, which required much timber for her merchant marine, may have established her Pontic colonies of Synope, Amisus, Cerasus and Trapezus partly for the purpose of controlling her own ship supplies. Even Cyzicus could furnish timber from Mysian Olympus.

The busy maritime cities of eastern Greece, located in the rain shadow of the Grecian highlands, were even more dependent upon imported lumber, because their local hills and mountains, according to Theophrastus, yielded only inferior woods. Megara, when she founded the colony of Heraclea Pontica on the Euxine, selected a spot which today, as the modern Eregli, has the reputation of being unusually rainy and well timbered.[59] Heraclea was therefore designed to exploit for Megara's benefit the forests of the Pontiac ranges as well as the abundant yield of the coast fisheries there. Athens, whose local mountains were practically denuded of their forests in the time of Plato,[60] brought lumber from great distances, both for naval purposes and for building. Even fencing and beams for the Laurion mines came from over sea.[61] The construction of lumber rafts equipped with sails was familiar to the Greeks. Athens occasionally secured ship timber from Phoenicia or Cyprus, and undoubtedly organized her vast Pontic trade in the days of her maritime empire with a view to the importation of Pontic lumber. She drew also upon the forest supplies of the west. The speech of Alcibiades revealing to the Spartans the Athenians' motives for the Sicilian Expedition specifies the control "of the ship timber which Italy supplies in such abundance,"[62] and points to an established lumber trade with the Greek colonies of Magna Graecia and Sicily. A century later Theophrastus shows so detailed a knowledge of Italian woods[63] as to indicate their presence in the Athenian market, whither they had come in exchange for manufactured Greek wares. "The tall pines and crested oaks" of Sicily had been famous from Homeric days.[64]

The nearest and most abundant supply of good ship timber for the cities of eastern Greece was found in Thrace and Macedonia,[65] where a northern location, moderate summer showers and extensive mountain ranges insured considerable forests. The best watered and therefore

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59 R. Fitzner, *opus cit.*, p. 80. E. Banse, *Die Turkei*, p. 83. Berlin, 1919.

60 Plato, Critias, chap. v, p. 418. Trans. by Henry Davis. London, 1870.

61 A. Broeckh, The Public Economy of Athens, p. 138. Trans. from German. Boston, 1857.

62 Thucydides, vi, 90.

63 Theophrastus, *Hist. Plant.*, Bk. iv, ch. v, 5.

64 Odyssey, ix, 112-120, 186.

65 Xenophon, Hellenes, Bk. vi, ch. i, 11.

the best wooded section lay between the Strymon and Hebrus rivers. The coastal plain here receives about 25 inches (625 mm.) of rain annually, but the great Rhodope highland forming its hinterland has 30 to 40 inches or more (750 to 1,000 mm.).[66] There at the mouth of the Strymon River lay the important Athenian colony of Amphipolis, founded only after repeated efforts, owing to the hostility of the local tribes.[67] Significantly enough, its site had previously been selected by an abortive colony from Miletus.[68] Contiguous to this region, less rainy, but offering protected sites for coast settlements, was the Chalcidice Peninsula, colonized by Chalcis, Eretria, Andros and Corinth. All these cities doubtless counted chiefly on the forest products among the raw materials which were the natural exports of a new and backward region.

Theophrastus recognized the general superiority of the northern timber.[69] The woods imported into Hellas for building and carpentry work he graded according to quality, as follows: Macedonian, Pontic, Mysian-Olympian, Aenianian from the high slope of the Oeta (7,078 feet or 2,158 meters) and Tymphrestus ranges (7,606 feet or 2,319 meters) in northern Hellas, down to the poor knotty timber from Mount Parnassus and the Euboean ranges. Wood of variable quality was also brought from highland Arcadia,[70] where the peaks have considerable forests even today. All the maritime cities made a steady demand for the strong, light, durable Macedonian fir, which was used for oars, masts and sailyards. Athens imported this timber through her colony of Amphipolis, which commanded the forests of the Strymon River basin. Therefore she was dealt a heavy blow when this town and its port of Eion were captured by the Spartans in 424 B. C. during the Peloponnesian War, since her navy needed constant replenishing.[71] Later the expansion of Macedon over all this coast as far as the Hellespont excluded Athens from her nearest and surest lumber supply, and jeopardized her sea connection with the Caucasus and Pontic forests, until her incorporation into Phillip's empire again opened these sources of supply. Athens revolted from Cassander in 305 B. C. and forfeited her right to use the Macedonian forests. Then she turned to Demetrius of Syria and was promised timber for a hundred war ships.[72] The wood doubtless came from the Lebanon range.

66 F. Trzebitsky, *Niederschlagsvertheilung auf der Sudost-Europaischen Halbinsel*, *Pet. Geog. Mitt.*, vol. lv, pp. 186-7. Gotha, 1909.

67 Thucydides, i, 100; iv, 102.

68 Herodotus, v, 124-126.

69 Theophrastus, *Hist. Plant.*, Bk. i, ch. ix, 2.

70 Ibid. Bk. v, ch. ii, 1.

71 Thucydides, iv, 108.

72 Plutarch, Lives, Demetrius, x.

The Macedonian forests long remained the chief source of lumber for the Aegean states.[73] In 158 B. C. we find Rome prohibiting the export of ship timber from Macedon, evidently as a measure to cripple the commerce of Rhodes,[74] which was then the great middleman of the Aegean. These forests were not exhausted in Strabo's time, because the town of Datum near the mouth of the Strymon River on the Strymonic Gulf had dockyards for ship building,[75] evidence of accessible timber. But it must be remembered that this river drains an extensive highland region, which, owing to its elevation and northern location, gets a moderate rainfall in summer.

Deciduous trees, especially timber growth like the oak, ash, beech and chestnut, were widely distributed in northern and western Greece; but on the dry eastern side of the peninsula, where the rainfall rarely exceeds 25 inches, and in many localities falls far below, these trees were generally restricted to the mountains. The chestnut tree, still found in groves on Mount Olympus and the Pindus range, grows in Hellas at altitudes of 2,000 to 4,000 feet (600-1,300 mm.), but declines in size and abundance farther south. Theophrastus calls the sweet chestnut (*Castanea vesca*) the "Euboean nut." It grew on the Mysian Olympus and the Tmolus range of Lydia, whence it was called "the nut of Sardis," but was more abundant on the mountains of Euboea and the Magnesian Peninsula of Thessaly.[76] Near the foot of Mount Pelion, which still has its chestnut trees,[77] was located the Magnesian seaport of Castanea, mentioned by Herodotus and Strabo.[78] Thence probably the nutritious nuts were shipped to the large Greek cities, and took their name from the place of export, like the modern Brazilian nut. Today the best chestnuts are brought to Athens from the mountains of western Crete, where an altitude of 7,500 feet or more compensates for the southern latitude. This island, owing to its mountainous relief and its exposure to rain-bearing winds, was well wooded in ancient times[79] and supported a variety of trees, especially cypress[80] and cedar.[81] These helped to maintain the navies of King Minos and the fleets of the Cretan pirates, and met a steady demand for architectural purposes both in Athens and Rome. The finest and most abundant tree was the cypress, which grew very tall on the Cretan

73 Theophrastus, *Hist. Plant.*, Bk. iv, ch. v.

74 Mommsen, History of Rome, vol. ii, pp. 358, 364. New York, 1872.

75 Strabo, Fragments, 33, 36.

76 Theophrastus, *Hist. Plant.*, Bk. iv, ch. v, 4.

77 Leake, Travels in Northern Greece, vol. iv, p. 393. London, 1835.

78 Herodotus, vii, 183, 188. Strabo, Bk. ix, ch. v, 22.

79 Strabo, Bk. x, ch. iv, 4.

80 Theophrastus, *Hist. Plant.*, Bk. iii, ch. i, 6; ch. ii, 6; ch. iii, 3, 4.

81 Vitruvius, Bk. ii, ch. ix, 13.

mountains. It yielded a superior building and cabinet wood almost proof against decay.

Oak and beech groves were widely distributed over the mountains of Greece, and furnished mast for large herds of wild and domestic pigs. Oaks especially grew on Mt. Olympus and Pelion. They covered the low Calledromus range of eastern Locris[82] and Mt. Ptous in Boeotia.[83] They flourished on the Arcadian highlands and covered the heights of the Parnon range on the boundary between Argolis and Laconia.[84] The Laconian side of the high Taygetus Mountains, especially about the peak of Taletum, had forests in the second century A. D.[85] which were presumably fir and vallona oak groves such as Leake found there nearly a century ago.[86] The Taygetus Mountains now turn a bare rocky front to the Eurotas valley, except where the gulches retain soil and moisture. But the slopes, now washed bare of their humus or converted into terraced vineyards, were once mantled in oak trees which Theophrastus found characteristic of Laconia.[87] The modern traveler who motors from Sparta to Tegea in Arcadia, across the mountains forming the northern boundary of Laconia, finds these highlands (pass at 3,065 feet or 940 meters) covered with a poor oak brush, preyed upon by goats, which represents the degenerate successor of the pristine oak forests.

Western Peloponnesus presents even today a pleasant contrast to the bald eastern escarpment of Arcadia, which is located in the rain shadow of the central highland. The half of Greece lying west of the mountain backbone of the peninsula, formed by the Taygetus, Arcadian, Corax, Tymphrestus and Pindus ranges, has 30 inches (750 mm.) or more of rain a year. From the Gulf of Ambracia (Gulf of Arta) northward, the broad belt of coastal highlands is yet better supplied, and gets over 40 inches (1,000 mm.) annually; moreover, it receives slight summer showers to revive its vegetation, and these increase in frequency from Illyria northward.[88]

This western front of classical Greece had sufficient rainfall to maintain considerable forests, remnants of which still survive the depredation of the goats, where located far from human habitations. In ancient times even the plain of Elis had its oak groves and woods of wild pine.[89] Forests large enough to harbor abundant deer, wild boar

82 Herodotus, vii, 218.

83 Pausanas, Bk. ix, ch. xxiii, 4.

84 Ibid. Bk. viii, ch. xi, 1; ch. xii, 1; ch. liv, 5. Bk. iii, ch. xi, 6.

85 Ibid. Bk. iii, ch. xx, 4.

86 Leake, Travels in the Morea, vol. i, pp. 128, 132, 251. London, 1830.

87 Theophrastus, *Hist. Plant.*, Bk. iii, ch. xvi, 3.

88 Philippson, *Das Mittelmeergebiet*, p. 121, maps iii, iv. Leipzig, 1907.

89 Pausanias, Bk. v, ch. vi, 4.

and antelope covered the low hill country near Olympia and the higher Phoeloe Plateau,[90] which defined the boundary between Elis and Arcadia. There Xenophon and his sons used to range the forests for game before the crowds assembled for the Olympic Games.[91] The towering peaks of western Arcadia, which overlook the Elian plains, were well forested in ancient times. Mount Lycaeus was mantled in maples and oaks, and therefore was sacred to Zeus.[92] On Mount Erymanthus was staged the famous boar hunt of Hercules, which bears witness to mast groves of beech and oak. These trees grow on its slopes today, interspersed with planes; and in spring their tender green makes a background for the white blossoms of the wild pear tree.[93]

The northern flank of mighty Erymanthus belongs to Achaia, which today has the amplest forests of oaks and conifers to be found in all the Peloponnesus, and in ancient times must have been even more abundantly supplied.[94] The ancient province occupied the northern and northwestern escarpment of the Arcadian plateau, and sloped down from a succession of lofty peaks like Erymanthus (modern Olonos, altitude 7,300 feet or 2,225 meters), Panachaicus (Voidhia, 6,320 feet or 1,927 meters), Aroanio (Khelmos, 7,724 feet or 2,355 meters) and Cyllene (Ziria, 7,790 feet or 2,375 meters). These mountains today have oak woods on their middle zone and fir forests on their upper reaches,[95] owing to the rain-bearing winds that sweep through the Gulf of Corinth. In ancient times they undoubtedly furnished convenient supplies of timber to the shipyards of Corinth and Sicyon, because they offered a choice of cedar,[96] fir and oak.[97]

Across the Corinthian Gulf the mountainous coasts of western Hellas still have scattered woodlands which bear testimony to ancient forests. Parnassus, towering to the height of 8,070 feet (2,460 meters) behind the Crissaean Bay, has beautiful pine woods at 3,000 feet elevation; and its western slope is covered with a thriving, young growth of beech, oak, and conifers, through which the modern automobile road runs from Delphi north to Gravia. Groves of cypress and pine near Oeanthia in Locris in ancient times faced the Gulf of Corinth from this northern shore.[98] Naupactus, the important seaport and naval station of this coast, lay only ten miles from the Evenus River (modern Phidari) of Aetolia, whose valley was clothed in oak forests when Leake

[90] Strabo, Bk. viii, ch. iii, 32.

[91] Xenophon, Anabasis, Bk. v, ch. iii, 9-12.

[92] Pausanias, Bk. ix, ch. xxiii, 4.

[93] Leake, Travels in the Morea, vol. ii, p. 232. London, 1830.

[94] Pausanias, Bk. vii, ch. xxvi, 10.

[95] Leake, Travels in the Morea, vol. ii, pp. 112-117. London, 1830.

[96] Theophrastus, *Hist. Plant.*, Bk. iii, ch. ii. 5. Bk. iv, ch. i, 2.

[97] Pausanias, Bk. vii, ch. xxvi, 10.

[98] Pausanias, Bk. x, ch. xxxviii, 9.

visited it a century ago.[99] This stream flows out to sea between mountains over three thousand feet high, and reaches the coast between the sites of Homeric Calydon and the ancient Corinthian colony of Chalcis.[100] It doubtless brought down wood to build the Calydonian fleet which sailed for the Trojan War, and centuries later, ship timber to be exported to the treeless city of Corinth. All the mountains fronting this north coast of the Gulf of Patras were well wooded on their upper slopes a century ago, though cleared for cultivation below. Oak trees growing there were big enough to furnish the dug-out boats used in the navigation of the shallow Lagoon of Mesolongion between the mouth of the Evenus and the Achelous (Aspropotamo).[101] The Achelous River opened up the well-wooded mountains of Acarnania, which faced the rain-bearing winds from the west.

To the forests of the Ionian Islands Homer himself bears witness. He was familiar with "wooded Zacynthus," the tree-grown slopes of showery Ithaca, and the wind-swept woods of Neritus.[102] Abundant timber was one factor in the nautical development of all these western islands and coastlands from Zacynthus north to Epidamnus (Dyrrachinin or Durazzo) on the Illyrian seaboard. Moreover, the numerous colonies planted by Corinth on these coasts in Corcyra (Corfu) Ambracia, Leucas and Epidamnus[103] suggest that the mother city, poorly provided with wood, wished to assure her supply of ship timber for her big navy and merchant marine from these western sources. From these she could not easily be cut off by great commercial rivals like Aegina, Euboean Chilcis, and Athens, which lay on the Aegean side of the Isthmus, while Corinth could import the western lumber through her port of Lechaeum on the Gulf of Corinth.

The mountains surrounding the Gulf of Ambracia (Arta) a hundred years ago still abounded in large oaks and conifers well suited to naval construction. In 1788 and for seven years thereafter ship timber from these slopes was regularly exported from Prevesa to the French navy-yard at Toulon.[104] When Augustus Caesar planted the important naval base of Nicopolis at the entrance of the Gulf of Ambracia,[105] he chose the location with remarkable insight. This big inlet marked the southern border of Epirus and of the area of heavy rainfall with occasional summer showers, which characterized the Adriatic front of

[99] Leake, Travels in Northern Greece, vol. i, p. 108. London, 1835.

[100] Thucydides, i, 108.

[101] Leake, Travels in Northern Greece, vol. i, pp. 113-114. London, 1835.

[102] Iliad, ii, 361, 632. Odyssey, i, 246; xiii, 243-6; xiv, 1-2.

[103] Thucydides, i, 24, 30, 80.

[104] Leake, Travels in Northern Greece, vol. i, 163-6, 172, 181-2; vol. iv, 47-50. London, 1835.

[105] Strabo, Bk. vii, ch. vii, 5-6.

the Balkan Peninsula.[106] The forests of western Hellas culminated in the mountains of Epirus. There the famous oak grove of Dodona formed the earliest sanctuary of Zeus, the Thunderer. Beyond Epirus lay the rainy coasts of Illyria and Dalmatia, whose forests supplied the pirate fleets infesting these shores from ancient times.

According to the evidence, the crying need of eastern Mediterranean lands was for ship timber. A multitude of fishing smacks, naval vessels, merchant ships, and coastwise transportation boats kept up the demand for fir, pine, cedar and minor woods which entered into their construction. The coniferous forests were therefore constantly levied upon; and they were further depleted by the steady demand for pitch, tar and resin. Traffic in these usually accompanied the lumber trade, and emanated from the same sources of supply. Pitch and tar were doubtless procured from pine and fir trees in all parts of Greece, but the chief output came from the Caucasus, Phrygian Ida, and Macedonia, especially from the extensive coniferous forests on the northern slopes of Mt. Olympus and Mt. Pierus in southern Macedonia.[107] In Syria pitch was distilled from terebinth and Phoenician cedar,[108] and was exported thence to Egypt, where it was used, among other things, for treating the surface of the bulrush boats.[109]

The demand for all products of resinous woods was relatively greater in antiquity than now. They were employed for the preservation of ship wood and all ship equipments, for coating the interior of earthenware wine jars, and for the preparation of volatile oils, salves and ointments, which were almost universally used in ancient times. Resin and tar were the chief basis of cough medicines prepared by Greek physicians, and were ingredients of salves for external use. Oil of cedar, distilled from the Syrian cedar, was regularly used for these purposes, because its antiseptic or cleansing qualities were recognized.[110] It was exported from Phoenicia to Egypt where it was needed for embalming the dead.[111] The Romans used it for soaking wood as a protection against decay and insect attack.[112] This was the ancient forerunner of the modern creosoting process.

The Western Mediterranean Basin, owing to more ample and protracted rains, was fairly well supplied with timber in nearly all its

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106 F. Trzebitsky, *opus cit.*, pp. 186-7.

107 Vergil, Georgic III, 450. Pliny, *Hist. Nat.* xiv, 20. Theophrastus, *Hist. Plant.*, Bk. ix, ch. ii, 3-4; ch. iii, 1-4.

108 Theophrastus, *Hist. Plant.*, Bk. ix, ch. ii, 2, 3. Bk. iv, ch. vi, 1. Bk. iii, ch. xv, 4.

109 Exodus, ii, 3.

110 Naumann and Partsch, *Physikalische Geographie Griechenlands*, pp. 376-7. Breslau, 1885.

111 Herodotus, ii, 87. Pliny, *Hist. Nat.*, xvi, 11.

112 Vitruvius, *De Architectura*, ii, 9.

parts. This was true even of its African coast, because the high Atlas ranges tracing this littoral extract rain from the prevailing north winds. Hence they supported forests of big trees in ancient times.[113] The woods on the mountainous Rif coast of western Mauretania in places came down close to the sea, and clothed the promontory of Mt. Abila at the Strait of Gibraltar with a mantle of great trees.[114] These doubtless furnished timber for the ships of the Rif pirates who for two thousand years sallied out from that rugged littoral. The highest peak of the western Rif range, the modern Beni-Hassan, rises to an altitude of 7,216 feet or 2,200 meters, and lies only about twelve miles from the sea so that its timber was readily accessible. Farther east, in Algeria (ancient Mauretania Caesariensis and Numidia) the rainfall varies along the coast ranges from 24 to 32 inches (600 to 800 mm.), but exceeds this maximum in the great highlands of the Grand and Little Kabyle (ancient Byrinus Mons) where peaks towering to 7,000 feet or more get 60 inches (1,500 mm.).[115] This was essentially the region of the famous *Atlantis silva*,[116] or forests of a tree known to the Romans as the *citrus*, but quite distinct from the *citrus Medica* or citron. The tree was nearly related to the cypress, and yielded a beautifully variegated wood, which was imported into Italy for the manufacture of fine furniture and coffered ceilings.[117] Pliny identifies it with the thyon or thuya tree of the Greeks, which is still a product of Moroccan and Algerian forests, and is used by the Turks in their mosques as the choicest material for ceilings and floors. Among the ancient Romans the wood was highly prized and very costly. Tables of it sometimes measured four and a half feet in diameter, and sold in Cicero's time, before the days of degenerate luxury, for a million sesterces or twenty thousand dollars.[118] Martial reflects the popular estimate of the wood when he writes:

> Accipe felices, Atlantica munera, silvas:
> Aurea qui dederit dona, minora dabit.[119]

Some commentators identify this *citrus* with the *cedrus* or cedar tree of the Atlas Mountains, which Pliny rated as high as the cedars of Lebanon.[120] Vitruvius, who was an authority on architectural materials, made the same estimate of this wood. It was abundant in ancient as in modern times, and was exported to Rome. Beams of Numidian

113 Pliny, *Hist. Nat.*, v, 1.

114 Strabo, Bk. xvii, ch. iii, 4, 6.

115 Vidal-la-Blache, Atlas, map 2, p. 79. Paris, 1906.

116 Lucullus, x, 144.

117 Horace, *Carmina*, Bk. iv, 1, 20.

118 Strabo, Bk. xvii, ch. iii, 4. Pliny, *Hist. Nat.*, xiii, 15. Lucanus, ix, 416.

119 Martialis, xiv, Ep. 89.

120 Pliny, *Hist. Nat.*, xvi, 39.

cedar used in the construction of the Temple of Apollo at Utica[121] when the city was founded undoubtedly came from these forests. We must look to the same source for the ship timber which for centuries built the Carthagenian fleets.[122] Cork and tanners' bark have through the ages contributed to the trade of Saldae (Bougie) and Hippo Regius (Boné).

Owing to the more general distribution of forests in the Western Mediterranean Basin, the lumber trade seems never to have reached the development which it attained in the Levantine and Aegean Seas. In the days of Rome's splendor it brought building materials and choice cabinet woods from various regions to the rich and growing capital, and furnished ship supplies for the maintenance of the navy. Italy itself included the districts of heaviest rainfall and therefore of the best forests of ship timber, but certain other ship supplies, such as tar, pitch and wax, were economically produced elsewhere. Their bulk was small in relation to their value; so transportation charges were an almost negligible element in their market price.

Pitch was a regular article of commerce, procured from regions of ample coniferous forests; it was usually coupled with ship timber, resin, honey and wax. The Sila Mountains of the southern Apennines, today as in ancient times an important lumber region,[123] produced the famous Bruttium pitch of the Roman world.[124] This was evidently exported through the harbor of Narycium, the old Greek Epizephyrii, for Vergil couples the pitch-yielding forests with that city.[125] Gades (Cadiz) in southern Spain used the local ship timber for her own merchant marine, but supplied to Mediterranean commerce pitch, honey, wax and quantities of kermes berries or cochineal,[126] which point to oak forests. Cadiz and its vicinity get about 30 inches (750 mm.) of rain a year; but to the east rises the great Sierra de Volox with a peak 6,530 feet (1,960 m.), and from this range ample forest products were doubtless obtained. The still higher Sierra Nevada, culminating in the peak of Mulhaden (11,418 feet or 3,481 meters), and the northeastern extension of these highlands in the Sierra de Segura, rising in the Sierra Sagra to 7,872 feet (2,400 meters), were called by Strabo the mountain chain of the Bastetani, and described as thickly wooded with gigantic trees.[127] This was probably an exag-

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121 Ibid., xvi, 40.

122 E. Speck, *Handelsgeschichte des Altertums*, vol. iii, Part I, ¶ 522. Leipzig, 1905.

123 Pliny, *Hist. Nat.*, iii, 5. W. Deecke, Italy, pp. 428-430. London, 1904.

124 Strabo, Bk. vi, ch. i, 9. Pliny, *Hist. Nat.*, xv, 7.

125 Vergil, Georgic II, 438.

126 Strabo, Bk. iii, ch. ii. 6.

127 Strabo, Bk. iii, ch. iv, 2.

geration in view of the moderate rainfall of 20 to 30 inches, but the forests were ample enough to supply the Phoenician coast colonies of Malaca (Malaga), Maenaca, and Abdera. New Carthage probably drew the ship supplies for its busy port from Sierra Sagra by way of the Tader River (Segura), which rises on these high slopes. All the eastern Spanish littoral, except the Pyrenean coast, has a rainfall of 16 inches or less (400 mm. or less),[128] and therefore was compelled to import its timber from the mountains or from overseas. The juniper beams in the temple of Diana at Saguntum were said to have been brought by the original Greek colonists from Zacynthus.[129]

Southern Sicily has a meager rainfall, but Aetna and the mountains along the northern coast get sufficient precipitation for moderate forests. Early Greek legend represented it as well wooded, abounding in stately oak groves and open forest glades where cattle pastured.[130] Odysseus found this island of the Cyclops covered with trees, among them "tall pines and crested oaks."[131] Evidence of local ship timber is found in the big fleets maintained for centuries by the tyrants of Syracuse and other Sicilian cities. These enterprising rulers doubtless drew their main supply from the ample forests of Aetna;[132] and they may also have tapped the resources of the Sila Mountains across the Strait of Messina, in those periods when Syracuse extended its control over Bruttium.

Italy was the chief seat of the lumber trade in the Western Mediterranean, owing to the considerable rainfall (30 to 40 inches or more) on the Alps and Apennines. The eastern littoral, lying in the rain shadow of the Apennines, was poorly provided with timber; but the western and northern plains, even near sea level, had a goodly covering of forests as late as the end of the fourth century B. C. Both the hills and plains of Latium were well supplied with timber. Pliny and Livy mention numerous ancient woodlands in the vicinity of Rome.[133] Theophrastus considers Italy one of the important sources of ship timber accessible from the Mediterranean.[134] He praises the fir and pine of Latium, but finds them excelled by the tall coniferous forests of Corsica. He mentions the fine beech groves of the Latin plain from which the Etruscans got very long planks for the keels of their

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[128] Philippson, *Das Mittelmeergebiet*, p. 119, map iii. Leipzig, 1907.

[129] Pliny, *Hist. Nat.*, xvi, 40.

[130] Diodorus Siculus, iv, 5.

[131] Odyssey, ix, 112-113, 186.

[132] Strabo, Bk. vi, ch. ii, 8.

[133] Livy, *Historia Romae*, i, 30, 33; ii, 7. Pliny, *Hist. Nat.*, xvi, 10, 15.

[134] Theophrastus, *Hist. Plant.*, Bk. iv, ch. v, 5.

ships, and comments on the abundant growth of oak, laurel and myrtle on the promontory of Circei.[135]

Hence during Italy's early centuries of retarded economic development, when she furnished only raw materials to commerce, one of her chief items of export was ship timber.[136] It is probable that firs and other woods from the northern Apennines figured in the early commercial dealings of the Etruscans with the Carthaginians, for the domestic timber of the latter was comparatively limited in variety. Greece, as we have seen, probably drew upon Italian lumber, both from the mainland and from Corsica. The forests of Corsica reached down to the shore; they were therefore readily accessible and made the island an object of conquest. At some very early date timber was cut there by the Romans, and conveyed away on rafts provided with sails. One of these was broken up by a storm and lost.[137] It was probably these wooded shores of Corsica which gave the island a high repute far away on the Ionian coast of Asia Minor, and which induced the ancient colonists from Phocaea to settle there. The Etruscans expelled the strangers from this choice forest reserve, and for centuries after exacted a tribute of pitch, honey and wax from the island.[138] Later the Romans exploited its fine boxwood, for box trees grew there to extraordinary height.[139] The familiarity of Theophrastus with this particular Corsican product[140] suggests that it was imported into Greece, where the hard, close-grained wood was used in carving images of the gods.[141]

The early Etruscans sought timber far afield because of some peculiar fitness for their purposes, like the long beech logs of Latium,[142] or because of its superior accessibility. They had ample wood at home, owing to the northern location of their district and its numerous mountain ranges. The Ciminian forest covering the hill range of Mt. Ciminius in southern Etruria was, in 310 B. C., considered as frightful and impassable by the Roman army as were the vast German forests centuries later. Not even a trader with his pack mule dared to traverse it.[143] In the Second Punic War a fleet of thirty ships was contributed by the Etruscan cities to the navy of Rome. The timber was donated by Volaterrae, Clusium and Perusia, all located in the hills of Etruria, and Rusellae on the coast, which commanded the fir

135 Ibid. Bk. v, ch. viii, 1-3.

136 Mommsen, History of Rome, vol. ii, p. 255. New York, 1906.

137 Theophrastus, *Hist. Plant.*, Bk. v, ch. viii, 2.

138 Diodorus Siculus, v 13.

139 Ibid, v, 1. *Pliny, Hist. Nat.*, xvi, 16.

140 Theophrastus, *Hist. Plant.*, Bk. iii, ch. xv, 5.

141 Ibid. Bk. v, ch. iii, 1, 7.

142 Ibid. Bk. v, ch. viii, 3.

143 Livy, *Hist. Romae*, ix, 35-36.

forests of the Umbria River basin.[144] The Tiber river with the tributary Clanis, Tinia, Nar and Anio, tapped the Apennine forests of Etruria, Umbria, and the high Abruzzi Plateau of the Sabine country, and brought thence the immense supplies of lumber required by the growing capital of Rome.[145] From these sources came the longest and straightest planks used in Rome to build its villas, palaces and temples during the time of Augustus.[146]

Where the Apennines bend westward and trace the Ligurian coast, they get over 50 inches of rain a year. Their rain-drenched slopes were therefore covered with dense forests in ancient times. Trees grew there to immense height and sometimes measured eight feet in diameter. Much of the wood was very superior, beautifully veined, and equal to cedar for cabinet work. This, together with excellent ship timber, was exported through the port of Genoa.[147] The Roman naval base of Luna, located in a deep bay (Bay of Spezia) on the southern edge of the Ligurian Apennines, undoubtedly drew thence its abundant ship supplies. This choice timber of the northern Apennines had once been employed in constructing the vessels of the Etruscan pirates; later it built the triremes of ancient Pisa for her long wars against the Ligurian pirates,[148] and later still the growing fleets of Rome. In the Middle Ages it equipped the merchant marine and navy of both the Pisan and Genoese Republics, when competing for the trade of the Mediterranean and fighting Saracen pirates.

Northern Italy had abundant timber also on the Alpine slopes and in the Po valley, but these supplies were in general too remote from the big centers of population in the south for the export of crude lumber, unless in response to a special demand. Larch trees which were found only in this northern district and which furnished very long, straight timbers, were transported from the Alpine valleys by the Po River to Ravenna, and from there were distributed along the neighboring coasts as far south as Ancona; but they could not stand the costly haul to Rome.[149] However, Tiberius Caesar, needing long beams for the construction of a bridge over his *naumachia*, ordered larch trees to be cut on the Rhaetian Alps and brought to Rome. One of these large logs was 120 feet long.[150] The finest bird's eye or "peacock" maple to be found anywhere came from the Rhaetian Alps and the hill ranges of the Istrian peninsula. It ranked with the famous

144 Ibid. xviii, 45.

145 Strabo, Bk. v, ch. ii, 5; ch. iii, 7.

146 Strabo, Bk. v, ch. ii, 5.

147 Strabo, Bk. iv, ch. vi, 2.

148 Strabo, Bk. v, ch. ii, 5.

149 Vitruvius, *De Architectura*, Bk. ii, ch. ix, 14-17.

150 Pliny, *Hist. Nat.*, xvi, 39-40.

citrus wood in point of beauty, and was so valuable for cabinet work[151] that it could bear the heavy transportation charges to distant Rome.

Ship timber from the eastern Alps was undoubtedly floated down to the Adriatic in very early times to build the Etruscan merchant ships at Adria and Spina, and later to equip the transport and naval vessels of the Romans in the ports of Aquileia and Pola. On a larger scale, however, forest products of small bulk, such as resin, pitch, honey and wax, were contributed by the tribes of the eastern Alps to Mediterranean commerce in exchange for food stuffs, and were shipped from Aquileia and other Adriatic ports.[152] Fine resin used in medicine came from the foothills of the Italian Alps.[153] Cisalpine Gaul had extensive pitch works, and manufactured huge wooden wine casks lined with pitch, which aroused the admiration of Strabo.[154] This cooperage business was coupled with an active and long established pork-packing industry, for the abundant mast in the oak, beech and chestnut groves of the Po valley supported large herds of swine.[155]

The Mediterranean coast of Transalpine Gaul and its Rhone valley hinterland, owing to its northern location, had ample forests. These furnished timber for the rafts and dugout boats which forwarded native traffic on the river;[156] and also equipped the merchant marine of the Greek traders of Massilia from the sixth century B. C.[157] An ancient export trade in ham and bacon from the Rhone valley to Rome indicates mast groves in this district, while a similar trade from the eastern Pyrenees points to forests there.[158] The conifers of the Pyrenean hinterland of the Mediterranean, nourished by a rainfall of 30 inches (750 mm.) or more, undoubtedly maintained the merchant fleets of the ancient Greek colonies of Emporiae and Rhoda, western outposts of the Massiliot settlements, while the woods of the Maritime Alps equipped the ships of the eastern outposts, Antipolis, Nicaea, and Portus Monoeci, as likewise of the native pirates, who raided Massilian commerce.

All this northern timber belt of the western Mediterranean lies within the limits of the middle-European forests. In ancient times it produced finer, more varied and abundant timber than was generally to be found in the southern districts. Moreover, the stretch from the Pyrenees to the Julian Alps long remained a colonial frontier of Rome, and hence served as a forest reserve after all the good timber of Latium

151 Ibid, xvi, 15.

152 Strabo, Bk. iv, ch. vi, 9-10; Bk. v, ch. i, 8

153 Pliny, *Hist. Nat.*, xvi, 11.

154 Strabo, Bk. v, ch. i, 12.

155 Polybius, ii, 15. Varro, *Rerum Rusticarum*, ii, 4.

156 Polybius, iii, 42. Livy, *Hist. Romae*, xxi, 26.

157 Strabo, Bk. iv, ch. i, 5.

158 Strabo, Bk. iii, ch. iv, 11.

and other densely populated districts of the Peninsula had been exhausted.

The denudation of the Mediterranean forests progressed rapidly in antiquity, especially in the Eastern Basin, which in the beginning was more scantily provided with timber and developed big centers of population and advanced civilization earlier than the Western Basin. Therefore its supply was small and the demand was great. Plato, in the fifth century B. C., deplores the reckless destruction of the forests and the consequent failure of springs and streams in Greece, owing to the rapid run-off of the rain from the bared hillsides. He also indicates that the Greeks for a long time had been turning their attention to raising forest trees by cultivation,[159] probably in an effort to maintain a local supply of timber for minor local needs. A century later Theophrastus complained that the supply of ship timber in the Eastern Basin was very limited, and that only the forests of Macedonia and Thrace remained fairly abundant.[160] In the same period the cedar groves of Cyprus were retreating from the coasts into the mountain interior of the island, though the woods of the Lebanon range still survived, owing to the elevation and westward exposure of the mountains. One is led to surmise also that those expert Phoenician woodsmen, who were commended by King Solomon, may have understood the fundamental principles of forestry and therefore have intelligently exploited their timber supplies. The small copses and meager woodlands of ancient Palestine were unable to stand the onslaughts of civilization. Therefore for Abraham and other ancient sheiks it was an act of merit to plant even a solitary tree by a pool or spring.[161] The Jews cultivated walnut and fig trees for the wood as well as for the fruit.[162] They regarded the destruction of their groves by fire as a visitation from on high,[163] and the wanton destruction of fruit trees in war as a heinous offense.[164]

In the Western Mediterranean, the recession of the forests became very apparent, but at a later date. Though the lumber trade of Italy was active enough to supply the large demand, ancient Roman farmers, as indicated by Cato's treatise on Agriculture, early began to raise plantations of various trees on their estates by irrigation, and thus supply their immediate needs for timber by local production. Under the Empire arboriculture was practiced on all Roman farms, as indicated by the instructions of Vergil, Varro, Columella and Pliny. The

159 Plato, Critias, ch. v, p. 418. Trans. by Henry Davis. London, 1870.

160 Theophrastus, *Hist. Plant.*, Bk. iv, ch. v, 5.

161 Genesis, xxi, 33.

162 G. Adam Smith Historical Geography of the Holy Land, pp. 80-81. N. Y. 1897.

163 Isaiah, x, 18-19.

164 Deuteronomy, xx, 19.

steady demand for cedar for the roofs of temples and palaces and superior buildings caused a restriction of the supply, for the best trees grew only in Africa, Crete, Syria and Cilicia.[165] In Pliny's time the superb forests of this wood on Mt. Ancorarius in Hither Mauretania were already exhausted.[166] Even before this Roman lumber ships sought the far away Caucasus ports. Denudation of the forests made such inroads upon the wood supply of Italy that by the fifth century Roman architectural technique had become modified to meet the growing scarcity and increased price of wood.[167]

Clearing for tillage land and the legitimate consumption of wood as lumber and fuel were only part of the process of destruction. The long dry summers and the predominantly resinous character of Mediterranean timber made forest fires especially frequent and disastrous, while the high winds of the hot season fanned the flames. Such fires were a commonplace in ancient Palestine. Isaiah describes one in a metaphorical passage: "It shall devour the briers and thorns, and shall kindle in the thickets of the forest, and they shall mount up like the lifting up of smoke."[168] Homer knows the effect of protracted drought and strong summer winds upon such a conflagration. "Through deep glens rageth fierce fire on some parched mountain side and the deep forest beneath, and the wind, driving it, whirleth everywhere the flame."[169] The Greeks were familiar with the spontaneous origin of such fires in the mutual attrition of branches or trees in the dry season.[170]

Fires were often started, either intentionally or accidentally, by the herdsmen who ranged the mountain forests with their flocks of sheep and goats in the dry season. Burning improved the pasturage, because the ashes temporarily enriched the soil, and the abundant shoots from the old roots furnished better fodder. The forests once destroyed were hard to restore. Goats clipped the young growth from the hillsides as with shears. Trees which depended on deep root systems for their moisture could not survive the summer drought; saplings with shallow roots could not get a start. Moreover, there was no shade to help conserve the surface moisture in soil and root, at a season when the dry atmosphere was especially pervious to the sun's light and heat.

The chemical decomposition of rocks has always proceeded slowly in Mediterranean lands, owing to the lack of sufficient moisture for abundant plant life. Mechanical disintegration has also been slow,

[165] Vitruvius, *De Architectura*, Bk. ii, ch. ix, 13.

[166] Pliny, *Hist. Nat.*, xiii, 15.

[167] Kingsley Porter, personal communication.

[168] Isaiah, ix, 18; x, 17-19.

[169] Iliad, xx, 490-492. Also xi, 154-157; xxi, 340-349.

[170] Thucydides, ii, 77.

owing to the lack of intense cold. Hence both weathering processes have been weak, with the result that soil has accumulated by infinitesimal degrees, and has spread in a very thin mantle over the slopes. Except in the small silted valleys the rocks lie near the surface. Alluvial plains of considerable extent are rare; plains of loess or glacial clay are wanting.[171] The rock skeletons of Mediterranean lands are everywhere prone to thrust through the meager envelope of soil.

When the mountains were denuded of their forests, the violent autumn storms with their sudden downpour of rain scoured off the thin covering of earth from the steep declivities. The shield of foliage was no longer there to break the impact of the rain; the network of roots no longer held the light humus to the slopes. A stunted thorny scrub, the *maquis,* rooted in shallow pockets of earth, succeeded the denuded forests which formerly conserved and distributed moisture in the dry season, and preserved large areas for cultivation by irrigation.[172] Under the assault of the goats, the *maquis* even has grown shorter and thinner, exposing ever larger spaces to the scouring action of rain in winter and wind in summer, till mountains have become quite bare, as in parts of Greece and Spain. In many sections of the Mediterranean a single deforestation has meant denudation of the soil also and hence, the permanent destruction of the forests.[173]

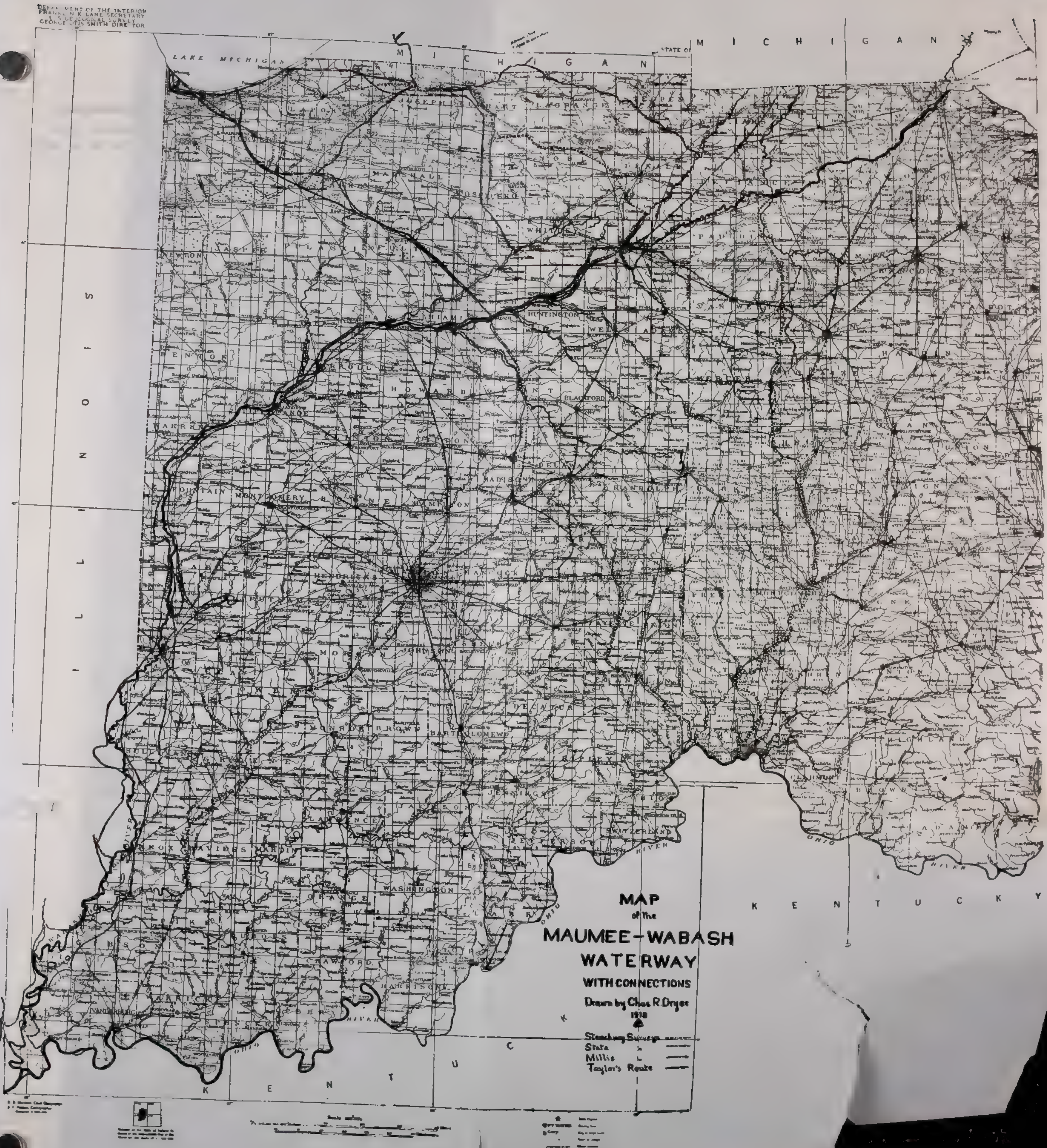
Hence all Mediterranean lands today show a low percentage of forested area, despite the predominant mountain relief which would naturally be devoted to tree growth. Spain has 20.8 per cent of her area in forests, Portugal 5.2 per cent, Italy 15.7, Greece, 9.3.[174] These are much lower percentages than are to be found in Germany, Switzerland, Norway or Japan; yet even these probably represent in part a low scrub and not genuine forests.

171 Philippson, *Das Mittelmeergebeit*, pp. 142-144. Leipzig, 1907.

172 M. Newbegin, Modern Geography, pp. 119-128. London 1911.

173 Philippson, *Das Mittelmeergebeit*, p. 144. Leipzig, 1907.

174 Ibid, p. 154.



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JENNINGS
WASHINGTON
HARRISON
HIGHLAND
OHIO RIVER
MAP
of the
MAUMEE-WABASH
WATERWAY
WITH CONNECTIONS
Drawn by Chas R. Dryer
1918
State
Millis
Taylor's Route

Annals of the Association of American Geographers
Volume IX, pp. 41-51; with 11 figures

THE MAUMEE-WABASH WATERWAY

CHARLES REDWAY DRYER

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Introduction.—The most important geographical feature between the Laurentian lakes and the Ohio river is the Maumee-Wabash trough. Its geological history and its complex and, in many respects, anomalous character render it of unusual interest to the physiographer, while its relations to travel and trade attract the attention of the historian and economist.

The axis of the trough extends from Lake Erie, southwest and south 420 miles to the junction of the Wabash river with the Ohio, approximately bisecting the space between Lake Michigan and the middle Mississippi on the northwest and the Ohio on the southeast. From the Erie end, the bottom rises 177 feet in 102 miles to a flat col at Fort Wayne, Ind., 750 feet A. T.; and thence falls 439 feet in 318 miles to the Ohio end. The trough is now occupied between Toledo and Fort Wayne by the post glacial Maumee river, at the col by a marsh 12 miles long and through the remainder of its length by the Wabash river and its tributary, the Aboite. (See Fig. 1.)

Preglacial Drainage.—Whether the Maumee-Wabash trough was traversed by a Tertiary stream carrying waters from the present Erie basin to the Mississippi, as suggested by Grabau,[1] is a question which promises little prospect of settlement. Such a stream would cross the Cincinnati arch, and the drift-buried gorge which it presumably occupied has not been discovered by hundreds of borings made for oil and gas along its course. The possibilities as to the extent of the preglacial

[1] Grabau, A. W., N. Y. State Museum Bulletin No. 45, pp. 42-6.

Wabash drainage system revealed by the studies of Tight,[2] Bownocker,[3] Capps,[4] Leverett[5] and others are indicated in Fig. 2.

The Wabash Trough.—*The Extra-Wisconsin or Flood Plain Section.*—The Wabash river crosses the Shelbyville moraine, where it escaped from the margin of the Wisconsin ice sheet, a few miles above Terre Haute, Ind., and 135 miles above its mouth. (Figs. 3-5.) This section of the valley is cut out of Pennsylvania shales, limestones and sandstones, nearly along the strike of the strata, to a depth of 250 feet and a width of six to twelve miles. It is now about half full of glacial outwash and surficially occupied by flood plain and gravel terraces, which diminish in height from 80 feet at the upper end to 20 feet at the lower. Occasional residual buttes rise from the valley floor 100 to 150 feet to the height of the bordering bluffs.[6] At the foot of the Shelbyville moraine it is joined by the preglacial valley of Raccoon Creek, one mile wide and 200 feet deep.[7]

The Preglacial Wisconsin Section.—The Wabash valley above the Shelbyville moraine as far as Delphi, a distance of 90 miles, is cut in Mississippian shales and sandstones to a depth of 250 feet and a width of three to five miles. This trench was filled nearly to the brim with glacial outwash, which has been subsequently removed to the extent of perhaps one-fourth, leaving very massive and continuous terraces 50 to 150 feet in height. Most of this outwash seems to have been brought in through large preglacial channels, one from the north along the present course of the Tippecanoe river, and one from the east along the present course of Wildcat creek.[8] The bottom of the trough at Lafayette is only 390 feet A. T. (Figs. 6, 7.)

The Glacial Section.—The extent and volume of the preglacial Wabash above Delphi is not certainly known. Between Peru and Wabash the present trench was joined by a tributary from the southeast which may have been the trunk stream. It may be in part the work of interglacial streams. Between Delphi and Huntington, a distance of 70 miles, the Wabash trough traverses Silurian limestones, which here form the crest of the Cincinnati arch and are disturbed by local arches and cones of quaquaversal or confused dip, in some cases

[2] Tight, W. G., U. S. Geol. Survey, Professional Paper No. 13, Plate I.

[3] Bownocker, J. A., American Geologist, Vol. 23, p. 175.

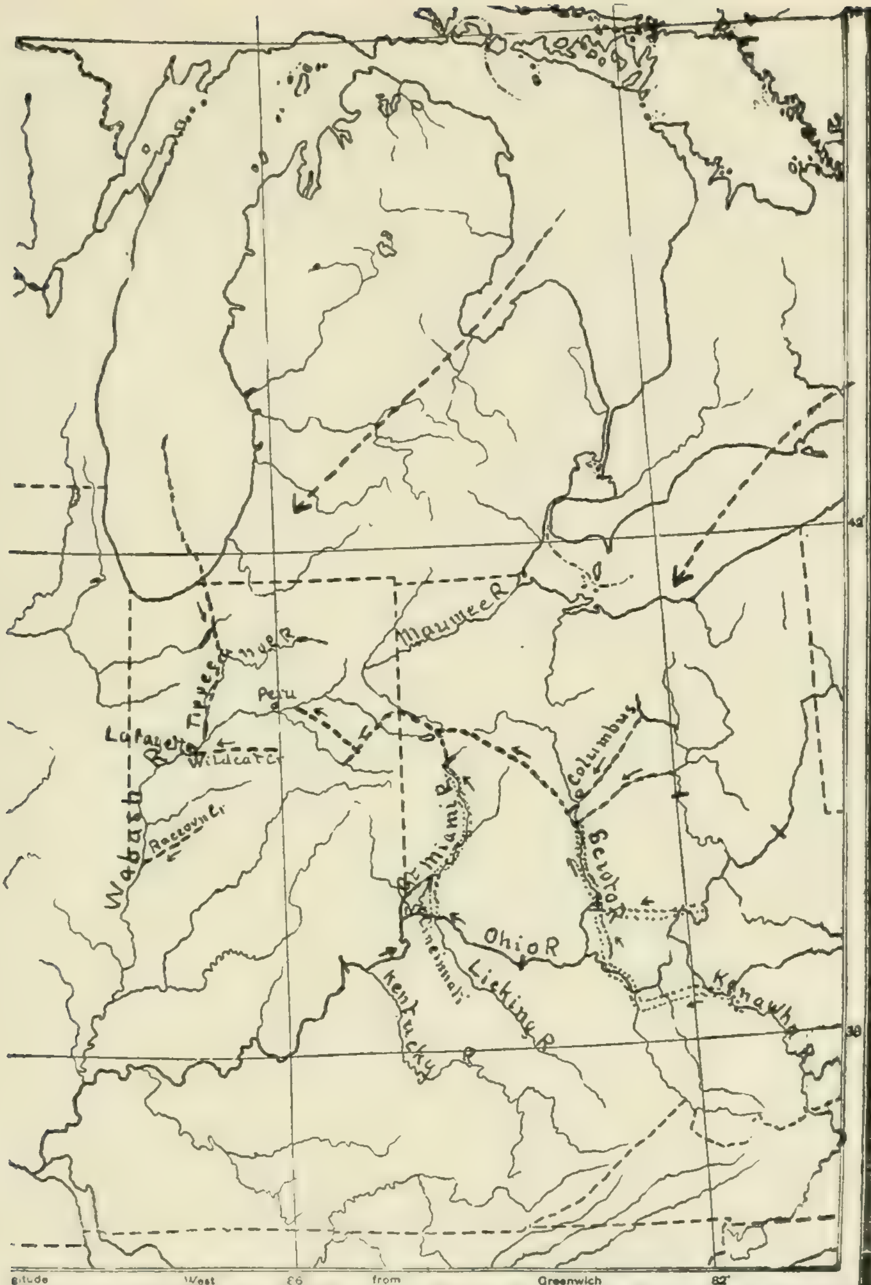
[4] Capps, Stephen R., U. S. Geol. Surv. Water Supply Paper No. 254, Plate II.

[5] Leverett, Frank, Journal of Geology, Vol. 3, p. 740.

[6] U. S. Geol. Surv., Princeton Folio.

[7] Dryer, Charles R., Proceedings Indiana Academy of Science, 1912, p. 206.

[8] Leverett, Frank, U. S. Geol. Surv. Monograph LIII, p. 59.



The Preglacial Wabash and Ohio
Open Valleys
Buried
Cols

Fig. 2

of high angle, the origin of which has been the source of much controversy.[9] This section is three-fourths of a mile to three miles wide, about 80 feet deep, and characterized by numerous limestone islands and terraces. The bluffs are in part limestone and in part glacial drift, in varying alternations horizontally and vertically. At Huntington, the present upper Wabash comes in from the southeast; but it is a very young post-glacial stream and has little to do with the character of the main trough. (Fig. 8.)

The Erie-Wabash Channel or Fort Wayne Outlet.—From Huntington to New Haven, a distance of 32 miles, the trough is 1 to 2 miles wide and 50 to 80 feet deep, and is known to glacialists as the Erie-Wabash channel or Fort Wayne outlet of glacial lake Maumee. The Erie-Wabash trough above Delphi owes its origin and character to the marginal drainage of the Huron-Erie ice lobe and the Maumee outlet. As the lobe receded haltingly or rhythmically, step by step, the marginal drainage was carried by four successive pairs of tributaries which followed the ice edge 50 or 60 miles on each side of the lobar apex, and possibly contributed, each in turn, a larger volume of water than the lake outlet. Of these, the last pair, the St. Joseph-St. Marys, was the most vigorous. As soon as the glacial margin withdrew from the Fort Wayne moraine, ponded waters expanded into glacial lake Maumee and overflowed into the St. Joseph-Wabash at the point of junction with the St. Marys. In the series of rapid changes through which the Wabash drainage system passed, this condition was of relatively long duration. The marginal streams had been loaded with outwash; the lake outlet was relatively clear; hence the removal of the filling from the Wabash trough was largely the work of the Maumee outlet. (Fig. 9.)

When the lake found a lower outlet into the Saginaw basin, the upper part of the Maumee-Wabash stream was gradually reversed, the St. Joseph and St. Marys were diverted to the lake, and the old outlet channel silted up. Thus, while the very striking pattern of willowy drainage which characterizes the present Maumee river is due to capture, it was not effected by the erosion of a more vigorous stream, but by the falling level of a temporary lake and the silting up of a flat divide. The capture is hardly yet complete, since during the high water of March, 1913, the St. Marys discharged nearly one-third of its water through the old channel into the Wabash.

The Maumee Trough.—The present Maumee river is the successor of glacial lakes Maumee, Whittlesey and Warren. From Fort Wayne

[9] Kindle, E. M., American Journal of Science, Vol. 165, p. 459.

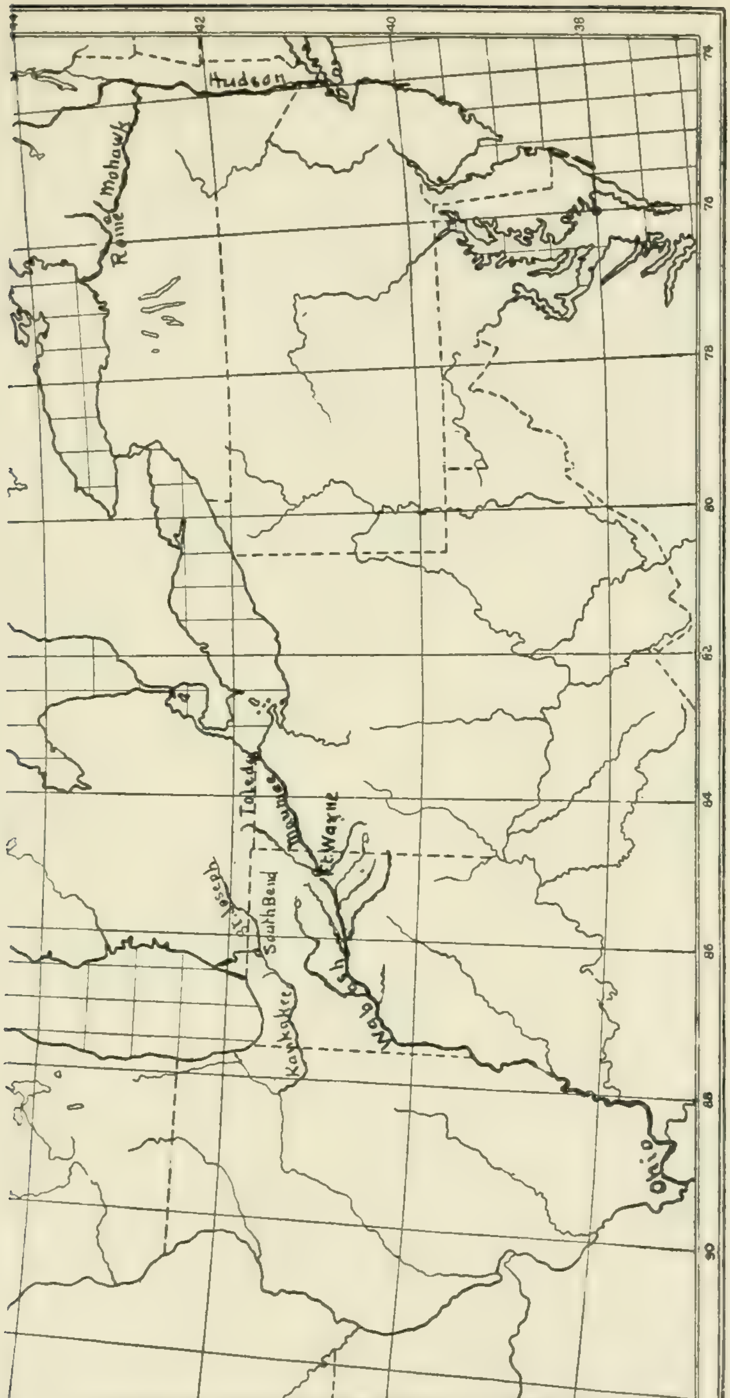

Hudson
Mohawk
Rome
Toledo
Maumee
Ft. Wayne
St. Joseph
South Bend
Kankakee
Wabash
Ohio
44
42
40
38
74
76
78
80
82
84
86
88
90

FIG. 10

to Defiance, O., it is sinuous and sluggish with drift bluffs and bottom. Below Defiance its bed is on or near Devonian limestones and is broken by rapids.

SUMMARY.—The distal half of the Maumee-Wabash trough was made by a preglacial stream, comparable in age and volume with the lower Ohio. The location of its extreme headwaters is conjectural and may have been in northern Michigan, in southern Ontario, in North Carolina, or in all three. The proximal half of the trough is chiefly the product of glacial and post-glacial drainage, which extended headwards *pari passu* with the recession of the Huron-Erie ice lobe, culminating in a succession of ice-dammed lakes and was finally reversed by the eastward outflow of Lake Erie. The Maumee-Wabash trough is the correlative and homologue of the Mohawk-Hudson trough, the Fort Wayne outlet corresponding to that at Rome, N. Y., the Wabash-Ohio to the Mohawk, and the Mississippi to the Hudson. (Fig. 10.)

THE WATERWAY.—The Maumee-Wabash trough has been for centuries an actual or potential link and trade route between the Laurentian lakes and the Mississippi and has had two periods of special prominence.

The Canoe Period.—Previous to 1783 it was a great highway for Indians and white explorers, fur traders and military forces. The French found an entrance to the heart of the continent through the back door by way of the curiously connected headwaters of the St. Joseph-Kankakee and the Maumee-Wabash. The upper lakes led them first to the shorter but more difficult route via the portage at South Bend, Ind., which La Salle followed in 1679. The maps of the seventeenth century do not show the Maumee-Wabash route, but either confound the Wabash with the Ohio or make it flow westward through central Ohio, Indiana and Illinois to the Mississippi. In 1699 D'Iberville led his colonists from Quebec to Louisiana by the Maumee-Wabash route, making it a link in the main line of communication which held the French possessions in America together. In 1720, under authority from Detroit and Quebec, a military post was established at the Wea village just below the present site at Lafayette, Ind., and called Post Ouiatenon. About the same time a French trading post was established at the Miami village at the head of the Maumee, where Fort Wayne now stands, and called Post Miamis. In 1731 Vincennes established on the lower Wabash, under the jurisdiction of Louisiana, *Au Poste*, afterwards called by his name, which remained for nearly a century the most important human center in the northwest. During the eigh-

teenth century the Maumee-Wabash canoe route reached its climax of usefulness and was followed by Indians, French and British, often in strong force. It acquired the fanciful name of "the Indian Appian Way" and the portage at its summit was called "the gateway of the west." The Miami Indians supplied carts, pack horses and carriers, sometimes at the rate of $100 a day. In 1778 Lieutenant-Governor Hamilton's British force was helped on its way to occupy Vincennes by the beavers. After the breaking of their dam had let the boats pass on a flood of water, the animals in a short time repaired it and the process was repeated. When in 1783 the territory came under the jurisdiction of the United States, the period of through canoe travel came to an end and the Maumee-Wabash waterway was little used for half a century.

After the organization of Indiana Territory in 1810 with its capital at Vincennes, all sorts of craft, canoes, pirogues, batteaux, "broadhorns" and "arks" pushed up the Wabash and its tributaries, carrying white settlers. In 1823, stern-wheel steamers began to ascend the river to Lafayette, sometimes to the number of fifty or more during the spring high water. These crafts remained important until displaced by the railroads, and are still in local use.

The Canal-boat Period.—A canal at the Fort Wayne portage is said to have been projected as early as 1804. The war of 1812-1814 demonstrated the need of transportation for military purposes and a survey was made for a canal by Captain Riley in 1818. When in the second and third decades of the nineteenth century a mania for internal improvement swept over the northwest, obvious geographical advantages attracted attention strongly to the Maumee-Wabash route. The impetus toward extensive canal construction was powerfully stimulated by the success of the Erie canal through New York. The state of Ohio began the construction of the Miami and Erie canal from Cincinnati to the Maumee at Defiance and thence to Toledo in 1825. The Wabash and Erie canal was constructed from Toledo to the Ohio-Indiana line in 1842 and the Miami and Erie canal connected with it in 1845. It is interesting to note that the latter canal has never been officially abandoned. It is still nominally open, but perhaps more useful for political than for economic purposes. Schemes for its restoration and improvement are now being actively promoted.

In Indiana, ground was broken for the Wabash and Erie canal at Fort Wayne in 1834 and three years later the summit section was opened to Huntington. The waterway from Maumee Bay to Terre Haute was complete in 1847. Along the Wabash it followed closely the foot of the bluffs and terraces, which formed the berm bank. In 1853 the canal was extended to the Ohio at Evansville, but the bell of

the locomotive had already tolled its death knell. It cost $7,300,000 and nearly bankrupted the state, but it brought half a million people from New England, New York and Pennsylvania into Indiana, shifted trade from the Mississippi and New Orleans to Lake Erie and New York, transferred the center of population and wealth from the south to the north, changed the character and connections of the commonwealth, and determined the great part which it subsequently played in the Civil War. With the abandonment of the canal, the Wabash trade route ceased to exist, except in so far as it furnished an easy grade for railroad construction, occupied, except for short intervals, as far as Terre Haute. It is worthy of note that the preglacial section below the Shelbyville moraine was not followed by the canal, which cut across country from Terre Haute to Evansville, and has been generally avoided by railroads.

The Lake Erie-Lake Michigan Waterway.—The present epoch of agitation for waterways has given birth to a project for connecting Lake Erie and Lake Michigan by a barge or ship canal. This project involves the canalization of the Maumee river from Toledo to Fort Wayne, and the construction of a canal from Fort Wayne across country to some point near the head of Lake Michigan, preferably and ultimately Chicago. Although the history of this canal does not date back so many centuries as that of the Suez or Panama, it possesses a respectable antiquity. Indians and Frenchmen paddled, pushed and carried their canoes over the high moraine from the St. Joseph-of-the-Maumee to the St. Joseph-of-Michigan. In 1829-30 Howard Stansbury, a government engineer, subsequently of Great Salt Lake survey fame, surveyed two routes between the Maumee-Wabash trough and Lake Michigan. (Fig. 1.) The comprehensive scheme of internal improvements authorized by the Indiana legislature of 1836 provided for a canal from Fort Wayne to Michigan City, a few miles of which was actually constructed. In 1875 Major Gillespie of the U. S. Engineer Corps resurveyed and approved Stansbury's route from Lake Michigan to the Wabash at the mouth of the Tippecanoe. In 1895 Dr. William T. Harris of Defiance, Ohio, began to collect data and publicly to agitate the project for a canal from the Maumee to Michigan City by either the northern Stansbury or the Indiana improvement route. On November 16, 1907, the Toledo, Fort Wayne and Chicago Deep Waterway Association was organized at Fort Wayne with a membership of 1,000. Under its auspices Frank B. Taylor, of the U. S. Geological Survey, published a brochure, giving data, map, profile and opinions of eminent engineers on the construction of a ship canal along the Maumee-Wabash trough from Toledo to Wabash, Ind., and thence directly northwest to Chicago. Through the efforts of the

Association the Congress of the United States in July, 1912, authorized a preliminary survey of this and other routes, which was carried out in 1913-16. An elaborate, almost exhaustive, report by Col. John Millis, Corps of Engineers, was submitted to the House in August, 1917, printed and distributed in 1918.[10] (Fig. 11.)

Colonel Millis's report discusses the canalization of the Maumee river from Toledo to Fort Wayne and the construction of a canal thence to Lake Michigan by two alternative routes, neither of which follows the Stansbury or state routes. One of them is substantially the route proposed by Taylor. The topographic engineering data may be briefly stated.

The Maumee Section.—The Maumee section extends from Toledo to Fort Wayne, a distance of 109½ miles. It follows the natural river channel to be canalized by a series of dams. The rise from 570 feet A. T. at Lake Erie to 740 feet at Fort Wayne is made by nine locks, varying from 14 to 25 feet lift.

The Northern Route.—The northern route leaves the Maumee-Wabash trough at Fort Wayne and extends directly west about 30 miles, thence northerly about 40 miles, past Warsaw, Goshen and Elkhart, thence westerly past South Bend to Michigan City. The length of the section is 133 miles. Six miles from Fort Wayne the canal rises by four locks 80 feet, to a summit level 820 feet A. T. and 60 miles long, from which it descends by 10 locks, 241 feet to the Lake Michigan level. The total distance from Lake Erie to Lake Michigan is 242.5 miles. An extension parallel with the shore of Lake Michigan to Indiana Harbor, 31 miles; to Calumet Harbor, 40.5 miles; and to Chicago Harbor, 52.5 miles, would make the maximum length 295 miles.

The Southern Route.—The southern route passes through the Fort Wayne outlet 25 miles to Huntington, thence north-westerly to a junction with the northern route near Gary. The length of this section is 150 miles and the distance from Toledo to Chicago 281 miles. The canal rises by one lock of 25 feet lift at Fort Wayne to a summit level at 765 feet A. T., 83 miles long, then descends by 8 locks 186 feet to the Lake Michigan level.

Ample water supply for the summit level of either route would be furnished by numerous morainic lakes in Indiana and southern Michigan, improved by a system of reservoirs and feeders.

Of the two, the northern route is favored by the engineers, on account of fewer aqueducts and deep cuts, avoidance of rock excavation and of

[10] Millis, John, House of Rep. 65th Congress, 1st Session, Document No. 343.

waterproof embarkments across the Kankakee marshes, better water supply, service of a larger local population, including the cities of Goshen, Elkhart, Mishawaka, South Bend and Michigan City and about $1,000,000 less cost.

The type of canal contemplated corresponds to that of the New York barge canal, having a minimum bottom width of 75 feet and a minimum depth of 12 feet, with locks 45 x 328 feet. The capacity of the canal is estimated at 7,500,000 tons annually. The estimated cost is by the northern route $135,078,248, by the southern route $135,956,195. Double locks will increase the cost about $12,000,000.

The Case for the Canal.—The principal considerations advanced by the promoters of the canal are as follows:

(1) It would form a necessary link in a continuous waterway from the Chicago district to New York, which would be practically of the same length as existing rail routes; and could be traversed by barges from end to end without trans-shipment of cargoes. This would bring about a decided lowering of freight rates.

(2) It would be about 400 miles shorter than the existing lake route by way of Mackinac.

(3) In addition to these advantages for through freight transportation, it would furnish water power and facilities for local traffic and thus promote manufacturing in a rich and populous territory of Indiana and Ohio.

(4) It would form a trunk line with which branches and feeders could be connected by way of the lower Wabash to the Mississippi, and by way of the Miami and Erie canal to the Ohio at Cincinnati.

(5) In case of war (with Canada), it would play a part similar to that of the Kiel canal in affording a protected passage for shipping.

(6) Shipping on the canal would not be exposed to loss by storms as on the Great Lakes.

The Case against the Canal.—The report of Colonel Millis is distinctly unfavorable to the project. The principal adverse considerations are as follows:

(1) The route of the canal between Fort Wayne and Lake Michigan cannot follow any important drainage lines or course favored by natural features, but must run against the grain of the country, crossing valleys, streams, divides and ridges.

(2) The initial cost of the canal is so large as to neutralize any possible advantages and to render its construction at present unjustifiable.

(3) The slower speed of canal boats as compared with lake boats renders the time of transit by canal and lake approximately equal and renders the shorter distance of little value.

(4) The cost of barges fitted to traverse Lake Erie might be so high as to require the trans-shipment of cargoes at both Toledo and Buffalo. This could be obviated by the proposed sheltered channel along the south shore of Lake Erie.

(5) The cost of carriage per ton mile would be three and one-half times that by the lake route and practically equal to that by rail.

(6) Local traffic and water power development would be of secondary and almost negligible importance.

(7) The existing natural lake route via Mackinac renders an artificial waterway unnecessary.

In a minority report of the Board of Army Engineers, Colonel Millis calls attention to events which modify the present discouraging aspects of the Michigan-Erie canal project. Water power and flood prevention developments, carried out by state and local authorities, are likely to extend up the Maumee to Fort Wayne. The rapidly increasing industrial interests of the Calumet district may demand inland water transportation from Chicago to Michigan City. When these conditions are realized, the construction by the Federal Government of a connecting link between Michigan City and Fort Wayne would "resemble somewhat the question of substituting a bridge or a tunnel for a ferry in a railway system or of building an expensive cut-off in lieu of a circuitous detour." Such a canal would form a part of "the spinal column of the transportation system of eastern North America."

Summary.—All the arguments for and against the use of artificial waterways in general apply to the Erie-Michigan canal, besides some peculiar to itself. The tonnage to be carried between its terminals is enormous and certain to increase. The demand for larger and cheaper transportation facilities is imperative. The problem of the part to be played by waterways in the future economy of the country is too complex to permit a clear view of its solution. The Erie-Michigan canal has legitimate claims to serious consideration. It would form a supplement and analogue to the New York barge canal. Its construction is feasible and free from unusual engineering difficulties. The geographical conditions are too favorable to be ignored, and perhaps in this case the saying of Geddes, "in the long run geography disposes," will come true.

NOTE.—The writer acknowledges indebtedness to Prof. Bernard H. Schockel, of the Indiana State Normal School, for invaluable assistance in fieldwork and in the preparation of the maps. The series showing the Wabash Trough was originally drawn as one continuous map, on the scale of one mile to the inch. In the process of engraving the parts have been unequally reduced. The scales are per inch approximately as follows: Figure 3, 3.5 miles, 4, 3.0 miles, 5, 4.0 miles, 6, 3.25 miles, 7 and 8, 5.0 miles, 9, 4.0 miles. The symbols used are: Flood plain and lake bottom, dotted: Alluvial terraces, circles: Limestone terraces, brick work.

WAR SERVICES OF MEMBERS OF THE ASSOCIATION OF AMERICAN GEOGRAPHERS

In compiling these records, all references to local services, such as are involved under the headings, Town Defence Committees, Loan Drives, Four Minute Men, Committee on Agricultural Production and similar titles, have been omitted.

Henryk Arctowski.

Worked for the "Inquiry" from December 8, 1917, till the middle of December, 1918.

January was in Paris. In February and March went with the Inter-Allied Commission to Poland and returned through Germany with Professor Lord.

Returned to America in May, 1919.

Preliminary Report on Poland. 106 pp., 29 maps. Prepared by Henryk Arctowski with the collaboration of E. deCzernutzki-Lazarovich-Hrebelianovich and S. J. Zowski.

Second Report on Poland. 27 pp., 3 maps, 1 table. Economic and engineering problems by Henryk Arctowski.

Third Report on Poland. 543 pp., 1 figure. Statistical data. Demography. Prepared by Henryk Arctowski with the collaboration of Sofia Bachurska and Arthur Hill.

Fourth Report on Poland. 280 pp., 13 plates, 8 maps. Statistical Data. Agriculture. Prepared by Henryk Arctowski with the collaboration of Sofia Bachurska and Wojciech Solowij.

Fifth Report on Poland. 77 pp., 4 plates. Statistical data on Bukowkna. Compiled by Henryk Arctowski with the collaboration of Wojciech Solowij and Hermine Ehlers.

Sixth Report on Poland. 346 pp., 8 plates. Discussion of statistical data. By Henryk Arctowski.

Seventh Report on Poland. 28 pp. Statistical data. Farm animals. Compiled by Henryk Arctowski with the collaboration of Wojciech Solowij.

Eighth Report on Poland. 34 pp., 2 plates. Miscellanea Polonica. Nos. 1-4. By Henryk Arctowski.

Joint Report on Poland. 30 pp. Contribution of Henryk Arctowski.

Tenth Report on Poland. 8 pp. The Four Dumas: Poles elected in the "9 Western Governments." Compiled by Henryk Arctowski.

Eleventh Report on Poland. 8 pp. Religious and linguistic data for the "9 Western Governments." Compiled by Henryk Arctowski.

Twelfth Report on Poland. 349 pp. Statistical data on Poland. Industry. Russian data, 1910. By Henryk Arctowski with the collaboration of Leon Jezioranski.

Thirteenth Report on Poland. 256 pp. Statistical data on Poland. Industry. Russian data, 1907. Compiled by Henryk Arctowski with the collaboration of Leon Jezioranski.

Fourteenth Report on Poland. 227 pp. Maps and statistical data on Poland. Industry. Austrian data, 1902. Compiled by Henryk Arctowski and Leon Jezioranski.

Wallace W. Atwood.

Appointed to the rank of captain in the R. O. T. C. Served in the training of men in map making, map reading, general surveying.

Instructor in the S. A. T. C.

Prepared geographical description of Camp Devens and vicinity which was published on the back of the special Camp Devens map by the U. S. Geological Survey.

Member of the National Research Council committee on geology.

O. E. Baker.

As head of the section of Farm Management, Department of Agriculture, entitled "Agricultural History and Geography," helped the "inquiry" and later the Commission to Negotiate Peace in the matter of providing information as to agricultural products of several foreign countries and trade in such products. Many maps were prepared showing the distribution of the principal crops and kinds of live stock in the Poland region, Austria-Hungary as it formerly existed, the Balkan area, and the former Turkish Empire, also for the former German Colonies in Africa, and some work was done on Russia and South America. Maps of trade and reports on trade in agricultural products accompanied the crop and live-stock maps.

Harlan H. Barrows.

Preparation with Professor Salisbury of a report on the "Environment of Camp Grant," for use by men in training there.

From July, 1918 to January, 1919, was Economist in charge of Country Studies, Bureau of Research, United States War Trade Board.

L. A. Bauer.

Was member of National Research Council (Division of Physical Sciences) and of several of its war committees.

Chairman of Committee of Navigation and Nautical Instruments of Council of National Defense, to advise Emergency Fleet Corporation and U. S. Shipping Board.

Directed and carried out various specific problems assigned by military and naval bureaus, and organizations.

Nels A. Bengston.

During 1917 gave special courses in Geography of Europe and in Field Mapping, University of Nebraska.

In 1918 was engaged in potash exploration work, and was later appointed expert on bread stuffs for Bureau of Research, War Trade Board. Held this position from July, 1918, to February 10, 1919.

Was then sent by the United States Department of Commerce as trade commissioner to Norway to investigate and report upon the economic situation in that country. Part of the duties were also to assist in changing from the blockade status of the war to the unrestricted trade that followed. Acted as commercial adviser to the American Minister at Christiania.

Hiram Bingham.

Air service, April, 1917-March, 1919.

Organized and directed U. S. Schools of Military Aeronautics, May-November, 1917.

Chief of Air Personnel Division, Washington, November, 1917-March, 1918.

Tours, American Expeditionary Force, April, 1918-August, 1918.

Commanding Officer Aviation Instruction Center, Issoudum, France, August-December, 1918.

Major Air Service, S. O. R. C., June, 1917.

Lieutenant Colonel, Air Service Aeronautics, October, 1917.

William Bowie.

At the time the United States entered the war, in charge of the Division of Geodesy of the United States Coast and Geodetic Survey. Immediately thereafter, got in touch with the Division of Military Mapping of the Corps of Engineers and arranged for the cooperation of the Division of Geodesy of the Coast and Geodetic Survey with the mapping forces of the Corps of Engineers.

The field work of the Division of Geodesy, after July 1, 1917, until the time the armistice was signed, was done entirely for the military authorities and consisted of control for military maps in the southern and eastern states.

In the office at Washington, the members of the Division of Geodesy made such computations as would furnish control for military maps and, besides, did a great amount of work in preparation of the pamphlets and tables on the Lambert Projection, which were used in the military maps of France and Belgium. These pamphlets and tables

were used to a very great extent by the officers of the American Army while training in this country and also in France.

August, 1917, commissioned a Major of Engineers and was assigned to the Division of Military Mapping of the Corps of Engineers. Discharged from the army on February 28, 1919.

While with the Corps of Engineers, devised a system of grid coordinates for progressive maps in the United States. As a result of the war, it was learned that it is necessary for the effective use of artillery to have a rectangular projection on military maps. No system in use in Europe would satisfactorily meet the conditions encountered in the United States where the area of the country is so great.

Prepared the specifications for the special defense maps of the United States. In the preparation of the tables, the Coast and Geodetic Survey cooperated with the Division of Military Mapping of the Corps of Engineers.

The results of the work on the grid tables have appeared as special publication No. 59, Coast and Geodetic Survey, entitled Grid System for Progressive Maps in the United States, by Major William Bowie, Chief of the Division of Geodesy, and by Mr. O. S. Adams, Geodetic Computer, both of the Coast and Geodetic Survey.

Isaiah Bowman.

Executive Officer and Geographer of the "Inquiry," an organization of about 150 persons. Under the supervision of the Department of State, this organization prepared scientific data for the peace conference. Its headquarters were at the American Geographical Society's building from November 10, 1917, to December 3, 1918.

Chief Territorial Specialist of the American Commission to Negotiate Peace and Executive Officer of the Section of Political, Territorial and Economic Intelligence, Paris, France, from December 4, 1918, to May 21, 1919.

At the personal request of President Wilson, returned to Paris on September 28, 1919, as Territorial Adviser, arriving home on December 21, 1919, with the Peace Delegation.

At various times in 1919 was the American representative on the following Peace Conference organizations:

a) Polish Commission, February-April.
b) Polish-Ukrainian Armistice Commission, April-May.
c) Jugo-Slav-Rumanian Commission, October-December.
d) Central Territorial Commission, October-December.

Alfred H. Brooks.

Chief Geologist, A. E. F., and on staff of Chief Engineer. Capt.

Engs. April, 1917; Maj. Engs. July, 1917; Lt. Col. Engs. October, 1918. Discharged from Army, May 3, 1919.

Record:

Training camp, May 14-July 29, 1917.

Sailed for France, August 14, 1917.

Reported to Chief Engineer A. E. F., September 2, 1917.

Investigation of military mining and relation of geology to field works in Arras-Vimy-Bethune sector, First British Army, October, 1917.

Investigation of geology, water resources, and field works on French front from Swiss border to Meuse River. About two months spent in field work on front, December, 1917-April, 1918.

Preparation of military geologic maps, water supply, and road metal reports and reports on physical character of terrain in Vosges Mts., Verdun sector. Some short field trips, but mostly office work. This included description of area within enemy's lines, May, 1918-November, 1918.

Preparation of summary reports on work of Geologic Section A. E. F. Application of geology to military problems, including work of German military geologists. Some field work was done, including trip down the Rhine, examination of the old front in France and Belgium, and a trip to Brussels to secure data on geologic work of the enemy, November 11, 1918-February, 1919.

Investigation of the iron and steel industry of northern France, Luxemburg, Belgium, and western Germany for Commission to Negotiate Peace. The special purpose of this investigation was to determine the use of the Lorraine iron ore. It comprised a statistical, economic, and geographic study of the data. Attached to Peace Commission doing above work at Paris, February 10, 1919-April 13, 1919.

At sea, Brest to New York, April 19-28, 1919.

Discharged from Army, May 3, 1919.

Charles F. Brooks.

Investigated for Chief of Weather Bureau the relation of ocean temperatures to long range forecasting with particular reference to the Western Battle Front in Europe.

Assisted in the preparation of maps in the Office of Farm Management, showing county distribution of crops requiring special labor requirements at certain seasons, the advance of the spring wheat, winter wheat and oats harvest, and the dates for seeding wheat to avoid injury by Hessian fly. These were published for general use and for use of the United States Employment Service.

From May to November, 1918, taught meteorology and weather

forecasting to the Signal Corps School of Meteorology at College Station, Texas; also taught meteorology and military road mapping in the Yale R. O. T. C.

Robert M. Brown.

Investigations in 1918 of the supply and depletion of oil and gas in Pennsylvania, Ohio and West Virginia.

James F. Chamberlain.

Taught course in Topography and the War to local S. A. T. C. unit.

William Churchill.

Committee on Public Information.

a. News censorship and control 1917-1918.

b. Temporarily *ad hoc* recalled to diplomatic duty by direction of the Secretary of State to prepare the American case on the disposition of the German Colonies in the Pacific.

G. E. Condra.

Organized and conducted State Congress on Conservation of Foods.

Director of Nebraska Conservation and Welfare Work.

Director of Military Survey of Nebraska, Chairman of sub-committees of State Council of Defense.

Gave course on Military Geography at the University of Nebraska.

Made special study of Potash Industry for Council of Defense.

Sumner W. Cushing.

As Captain in the Military Intelligence Division of the General Staff from July 29, 1918 to July 16, 1919, prepared and edited military handbooks and monographs and represented the War Department on various government committees, such as the Committee for the Selection of Maps to be used in the S. A. T. C. and the Committee on Economic Policy. The content of the military handbooks and monographs is largely geographical and is designed to give to a commanding officer all available data concerning his field of operations, so that he can lay sound strategical plans and order successful tactical movements. The monograph is also designed to assist officers in the administration of occupied territory.

N. H. Darton.

Chiefly concerned with a search for potash in the Redbeds of New Mexico and adjoining states.

As a member of a subcommittee of the National Research Council, gave considerable information regarding water supplies, etc., for camp

sites at several cantonments. As member of the U. S. Geological Survey, supplied data to the Army, mainly regarding camp sites near Washington.

Suggestion accepted that Fort Wingate, N. M., be selected for storage of part of great stock of TNT.

W. M. Davis.

In 1918 published "A Handbook of Northern France" of which nearly 4,000 copies were given to officers in various cantonments before they sailed for France, 5,000 were bought by the Y. M. C. A. for their hut libraries in France, and the balance were sold to the public.

Also, with aid of the Appalachian Mountain Club of Boston, prepared a guide book for "Excursions around Aix-les-Bains" our rest camp in the French Alps. 2,000 copies were sent to the Y. M. C. A. Secretary at Aix for free distribution.

Nevin M. Fenneman.

Division chief in charge of all scientific work in Africa, for Inquiry at American Geographical Society.

Chairman Research Committee, University of Cincinnati and arranged use of equipment for war purposes.

E. E. Free.

August 1917, entered army as Captain of the Ordnance Reserve Corps attached to the office of Chief Inspector of Small Arms Ammunition.

March 1918, assigned to Edgewood Arsenal, then a part of the Ordnance Department but later transferred to the Chemical Warfare Service. May, 1918, went to France on special duty in connection with the manufacture of war gases. On return in August, 1918, was attached to Edgewood Arsenal, still being used in connection with the manufacture of gases.

Discharged from the service June, 1919, with rank of Major, Chemical Welfare Service, United States Army.

H. A. Gleason.

Teacher in University of Michigan, conducting classes for the Student Army Training Corps.

James Walter Goldthwait.

Commissioned Captain, Military Intelligence Division, General Staff, April 8, 1918. Served until honorably discharged, Dec. 31, 1918, at Washington, D. C., first in charge of the map room of the Combat

Section, Military Intelligence Department, and later—from July 15th until December 31st, in charge of the Map Room of the Chief of Staff.

Work consisted principally in plotting promptly and accurately, in detail, news received by cable from all fronts, both as to changes in battle line and changes in disposition of troops, etc. Object of the work primarily to inform the Chief of Staff, Secretary of War and General Staff of the latest developments on all fronts, by graphic representation of news gathered from all official military and diplomatic sources abroad. Short oral reviews of the week's news were given, in the War Council Room to four groups,—Chiefs of Bureaus of the Army, Tonnage Conference group, House Military Committee, and Senate Military Committee.

Work developed under direction of Major Lawrence Martin, and was continued during his absence in Europe.

Herbert E. Gregory.

May 1, 1917, to September 1, 1917. In charge of the preparation of a special map of the Connecticut coast for Army and Navy purposes.

November 1, 1917, to May 1, 1918. Instructor in Reserve Officers' Training Corps, Artillery Unit, Yale University.

May 1, 1918, to July 1, 1918. Field investigations for the U. S. Geological Survey.

July 1, 1918, to October 1, 1918. With National Research Council, Division of Geology and Geography and Division of Educational Relations (part of the time as chairman of these divisions), engaged in selection of men for overseas duty, formulation of program of studies and preparing texts for the proposed Students' Army Training Corps.

October 1, 1918, to December 1, 1918. Educational director for the War Department for scientific subjects for the New England district, Students Army Training Corps.

A. J. Henry.

Replaced in the Washington Office of the Weather Bureau, another forecaster who was selected for duty in France.

Contributed to the preparation of Introductory Meteorology, issued by the National Research Council.

Ellsworth Huntington.

Enlisted in the Army June 6, 1918, with the rank of Captain. Served till July 18, 1919. Now Major in the United States Reserve Corps. Time spent entirely in Washington, first in the Military Monograph Sub-section; later made chief of separate section.

The work was the supervision of the preparation of geographic monographs and handbooks, giving every conceivable kind of informa-

tion in regard to countries where United States troops were operating or might be called upon to operate. A system was established which has been incorporated as a permanent part of the Army's plans for procuring the information which is inevitably needed in case of military operations in any part of the world. One of the largest pieces of work was the preparation of about sixteen little books on Russia and Siberia.

Mark Jefferson.

In charge of the map program of the "Inquiry" in New York from September 1 to December 2, 1918.

Sailed for Paris with the "Inquiry" on the George Washington.

Chief of the division of Cartography of the American Peace Commission in Paris till the end of May, 1919, and representative of the United States on the commission of expert geographers, representing the Great Powers, which exercised the final revision of all the lines and descriptions of boundary lines in the Treaties with Germany and Austria.

Worked for the Peace Commission in designing maps, mainly for the territorial experts and supervising their execution.

W. L. G. Joerg.

Indirect assistance in the preliminary work at the American Geographical Society of the American Commission to Negotiate Peace, known as the "Inquiry;" through the editing of articles and maps dealing with the geographical problems of the war for the Geographical Review; preparation of a series of pamphlets dealing with ethnographic and other topics to accompany a series of base maps prepared for the Inquiry; preparation for the Committee on Public Information of the official map of the new boundaries of Germany released to the press by that organization on May 7, 1919, with the summary of the peace treaty draft.

Douglas Wilson Johnson.

Chairman of the Executive Committee and one of the organizers of the American Rights League, a national organization active in mobilizing American public opinion in favor of entering the war against the Central Powers.

Author of the "Peril of Prussianism" a small book much used in pro-Ally propaganda in America, and reproduced in moving picture film propaganda in support of the war; also of "My German Correspondence" a letter to a German professor which went through large editions in French, Swedish, Portugese, and other foreign languages, and which was used by the British Ministry of Information in a

world-wide propaganda in support of the Allied cause; also of "Topography and Strategy in the War," a book much used by officers and men in the American Army, a special edition for the western front being issued by the National Research Council for distribution to army officers.

Member of New York Exemption Board No. 136, to select district quota for first draft army.

Member of Division of Geology and Geography, National Research Council, and as its foreign representative supplied the Council detailed reports on the use of geology and geography in the allied and enemy armies in Europe.

Member of staff of Experts assembled by order of the President at American Geographical Society to prepare data for the Peace Conference.

Commissioned Major in the Military Intelligence Division of the American Army, in January, 1918.

Detailed by the Secretary of War on a confidential mission to the European war fronts to study the relation of topography to strategy under modern conditions of fighting in Belgium, France, Italy, and the Balkans, March-October, 1918.

Appointed to study preparations being made in European capitals anticipating the peace conference.

Appointed by the Secretary of State as specialist in boundary geography with the American Commission to Negotiate Peace, December, 1918. Served as Chief of the Division of Boundary Geography, American Peace Commission, and as advisor to the President and Commissioners on various territorial problems, Paris, January-September, 1919.

Appointed by the Secretary of State to represent the American Government on the Roumanian, Jugoslav, and Central Territorial Commissions at the Peace Conference.

Technical advisor to the Department of State on European territorial questions, October, 1919.

William Libbey.

Entered service as Major, Ordnance Reserve Corp, February 1918.

Inspector of Rifle Demonstrators, visiting camps from Massachusetts to Alabama until May 1918.

Assistant Chief Instructor, Small Arms Firing School, Camp Perry, Ohio.

Promoted to Lieutenant Colonel, Infantry, September 1918.

Ordered to Washington as Chief Rifle Demonstrator October 1918. In charge of Demonstrators at the mobilization camps until November

1918. In charge of the work of examining, caring for, and preparing rifles for storage, as they were turned in by returning troops.

Honorably discharged, March 1919.

Alexander McAdie.

Enrolled as Lt. Commander in the U. S. Naval Reserve Force and served at home and overseas as Senior Aerographic Officer in the Navy.

There were trained at Blue Hill Observatory 58 graduates of 28 American Universities, of which 52 received commissions. 30 of these saw service in Ireland, France and Belgium.

G. R. Mansfield.

From July to September 1917, investigated the reported occurrence of coal in eastern Idaho, with a view to securing data that would help relieve the coal shortage that had been acute in that section the preceding season.

From December 1917 to April 1918, engaged with others in a detailed and quantitative study of the nitrate deposits of the Amargosa Valley in southeastern California to see if these deposits could be utilized and thus relieve tonnage in the Chilean nitrate trade.

In August 1918, collaborated with others in the preparation of the course in the geography of Europe for the S. A. T. C. of the War Department.

In October 1918, sent to New Jersey to study the glauconite deposits as a possible source of potash and to obtain quantitative data which could be useful in exploitation of the deposits.

C. F. Marbut.

The Bureau of Soils arranged its work the winter of 1918-19 in accordance with a request of the War Department so as to cover those areas in Georgia, South Carolina and some of the other states where the original map data desired by the War Department to make the Progressive Military Map of the United States was most deficient. In addition to doing this field work, the Bureau supplied the War Department with advance sheets of original maps of many counties which had previously been surveyed; also furnished certain data on the nature of the soil and sub-soil in places that were under consideration as posible sites for encampments of various kinds.

Prepared, at the request of the American Geographical Society, a map of the soils of Africa, based on the existing literature for the use of the Peace Commission.

Lawrence Martin.

Major, General Staff, U. S. Army

April to May, 1917, instructing students of University of Wisconsin in making maps as part of intensive course in military training.

May to July, 1917, civilian instructor in Topography in First Training Camp for Officers, Ft. Sheridan, Ill., after discharge from candidacy for commission because of defective eyesight.

August to December, 1917, 1st Lieut., N. A., Instructor in Topography, and Assistant to the Senior Instructor, Second Training Camp for Officers, Ft. Sheridan, Ill.

January to March, 1918, map officer of Military Intelligence, Army War College, Washington, D. C., also in charge of maps for the War Council.

March to July, 1918, Captain, N. A. ,in charge of Secret Map Room for Secretary of War and Chief of Staff, also giving weekly summaries of combat to Senate Military Committee, House Military Committee, general officers in charge of War Department bureaus, and chiefs of War Trade, War Industries, Shipping, and other boards, and assisting General March at conferences with newspaper correspondents; member of Division of Geography and Geology, National Research Council.

August to November, 1918, Major, General Staff, attached to G-2 (Military Intelligence), G. H. Q., A. E. F.; Military Observer with British corps on the Somme during advance from Albert to Hindenburg Line; with General Dickman's corps during St. Mihiel offensive; with one of General Bundy's divisions in the Vosges; attached to General Treat's Mission in Padua, and with various Italian and British units on the Italian Front, and with 332nd American Infantry in final offensive to and east of the Tagliamento.

November, 1918, to December, 1919, attached to American Commission to Negotiate Peace as Chief, Geographical Section, Military Intelligence, U. S. Army: (a) In Paris the first 6 weeks; (b) in Vienna and travelling throughout Austria-Hungary, Ukraine, and Roumania, January to June, 1919, engaged in getting maps for the Peace Conference and in geographical field work on territorial questions, including the Klagenfurt Basin problem of Carinthia, the Ruthenian problem of northeastern Hungary, the Vorarlberg-Liechtenstein problem of western Austria, the East Galician-Bukovina problem of Poland-Ukraine-Roumania, and the problem of the Germans of West Hungary (finally drawing the whole eastern boundary of Austria); (c) in Paris June to August, 1919, as geographical expert and member of various international subcommittees on boundaries, working on the modification of the Czechoslovak, Hungarian, and Austrian frontiers in the light of the notes from the Austrian Delegation, and on phases of boundary determination in Orava and Teschen between the Poles and Czechoslovaks, along the northern frontier of Jugoslavia, on the east coast of the Adriatic, in Thrace, in Bukovina, etc.; (d) August

24 to October 24, 1919, geographer to the Harbord Mission to Armenia, travelling by rail from Constantinople to the end of the Bagdad Railway in Mesopotamia, by automobile from Mardin to Diarbekr, Kharput, Malatia, Sivas, Amasia, Samsoun, Trebizond, Baiburt, Erzerum, and the old Russian frontier, then by rail to Kars, Erivan, Tiflis, and Batum; (e) November-December, 1919, in Berlin, Leipzig, Frankfurt-am-Main, and Coblenz; returned to United States, December 21, 1919.

Since January, 1920, on duty in Washington in Military Intelligence Division, General Staff, and working on certain phases of the Hungarian and Turkish treaties, for the State Department.

François E. Matthes.

1. Made special geographic and geologic examinations of the regions about Camp McClellan, Ala., and Camp Gordon, Ga., and prepared geographic descriptions of these areas for the use of the army. These descriptions were published by the U. S. Geological Survey on the backs of the topographic maps of Anniston, Ala., and Camp Gordon and Vicinity, Ga.

2. Made a special report on the geology of the Anniston region (with special reference to materials available for building, road construction, etc., and to water supply from wells, springs, etc.), at the request of the Quartermaster at Camp McClellan.

3. Assisted in translating from the French the *Manual for Artillery Orientation Officers,* the instructions contained therein being of particular value to the topographic engineers of the U. S. Geological Survey who were detailed to serve with the army in France in the capacity of Orientation Officers for the Heavy Artillery. The Manual was issued first by the U. S. Geological Survey, but a large edition with additional appendices has also been published by the Army War College.

It may be said in explanation that an Orientation Officer is essentially an expert in modern topographic methods who determines on the map the positions of batteries and targets and thus furnishes the battery officers with accurate data for long-range firing. The effectiveness of long range barrages and shelling generally in the late war depended largely upon the accuracy of the Orientation work.

Oscar Edward Meinzer.

On October 23, 1918, was commissioned Captain of Engineers and ordered to proceed to France for duty as a geologist, and as a ground water specialist.

Discharged from the Army December 14, 1918.

George J. Miller.

Application for Y. M. C. A. work still pending when war ended.

George E. Nichols.

Acted as Botanical Advisor on Sphagnum for American Red Cross: (Sphagnum moss was extensively used as a substitute for cotton in absorbent surgical dressing). My work here consisted in (a) exploration for sources of supply and directing similar investigations by other workers in various parts of the East; (b) passing judgment on material submitted for examination; (c) propaganda, both by letter and published articles.

Taught Military Mapping in Yale S. A. T. C.

Contributed to Gregory's textbook on "Military Geology and Topography."

A. E. Parkins.

During the fall of 1918, had charge of the S. A. T. C. work and taught geography, meteorology and map making and drawing courses at George Peabody College for Teachers.

Harry Fielding Reid.

Was a member of the Foreign Service Committee of the National Research Council which was sent to Europe in the spring of 1917 to report on the application of science to the conduct of the war.

G. B. Roorbach.

In May, 1918, was appointed Special Expert in the Division of Planning and Statistics of the United States Shipping Board and served in that capacity until September first, 1919.

During the period following the armistice, was appointed chairman of the Inter-departmental Committee for the Revision of Trade Statistics by Secretary of Commerce.

R. D. Salisbury.

Prepared a bulletin on the Geology and Geography of the Camp Grant region for use at the cantonment there.

C. S. Scofield.

With E. C. Chilcott, T. H. Kearney, made an expedition to Algeria, from August to November, 1918, at the request of the French Government, having in view the stimulation of wheat production in Algeria. Time in Algeria was about seven weeks, spent studying agricultural conditions and advising as to methods and machinery for increasing grain production, particularly under the semi-arid conditions of the high plateau of Algeria.

Ellen Churchill Semple.

Lectured before classes of officers, at Camp Zachary Taylor, on the military geography of the Italian front, during the autumn of 1917.

Worked for the " Inquiry " in New York City from December 1917 to December 1918.

Homer LeRoy Shantz.

Part of 1918 with " Inquiry " to determine natural plant resources and crop producing possibilities of large portions of Africa for the use of the Allied Peace Commission.

Representative of the Department of Agriculture as Agricultural Explorer, accompanying the Smithsonian African Expedition in South Africa, 1919.

J. Russell Smith.

April, 1917. Served as chairman of committee on agricultural service, University of Pennsylvania and within three weeks sent some three hundred boys to the farms in many states.

May and June, 1917. Wrote three articles, by special request, for the Country Gentleman, urging national food campaign.

April, 1917, to November, 1917. Served as chairman Food Commission, Philadelphia School Mobilization Committee, and chairman Food Section, Mayor's Home Defense Committee.

July and October, 1917. Articles in Review of Reviews urging League of Nations and ship-building campaign.

November, 1917, to June, 1918. Prepared 347-page report for Carnegie Endowment for International Peace, " Influence of Great War on Shipping."

July, 1918, to January, 1919. Special Trade Expert, Bureau of Research, War Trade Board, Washington, D. C., in charge of preparation of miscellaneous reports.

J. Warren Smith.

Service rendered in the preparation of climatological data of foreign countries to be used in the consideration of a peace program and conditions. In connection therewith, the division of Agricultural meteorology was given the general charge of compiling all climatological, agricultural and meteorological data concerning foreign countries for use by other branches of the Government.

The most important work done by the division was the preparation of very complete climatological maps of Africa.

Philip S. Smith.

Throughout the war, the main service rendered was as Administra-

tive Geologist and Acting Director of the Geological Survey. Article on the United States Geological Survey war work printed in Economic Geology, Volume 13, July 1918, pages 292-339, indicates the scope of the work of the administration of the Survey.

Served as geologist in charge of the sulphur and pyrites investigations, which furnished basal information regarding the production and status of these industries so important for the manufacture of acids needed in munitions work.

Member of the Division of Geology and Geography of the National Research Council, an associate member of the District of Columbia Legal Advisory Board for Draft Registrants, and a member of several committees investigating special problems, such as the Committee for the Selection of Maps for the Committee on Education and Special Training for the War Department, both for the Students' Army Training Corps and for "War Issues."

Walter S. Tower.

Service confined to work with the Division of Planning and Statistics of the United States Shipping Board.

Work consisted principally in general managerial duties of running the Division, which totaled about 325 people at the time the Armistice was signed, and in personal direction of the work on Import Program, by which efforts were being made to minimize the use of shipping for commercial purposes in order to realize for military needs the maximum tonnage possible.

Sent for a brief time in October 1918 to work with the American Section of the Allied Maritime Transport Council in London. Sent on return as one of the Shipping Board staff to Paris, to work in connection with the Commission to Negotiate Peace, and for something over two months remained there, both with the Paris office of the Shipping Board and with the American Section of Economics and Statistics of the Peace Commission.

T. Wayland Vaughan.

Requested, shortly before the United States entered the war, by the Director of the United States Geological Survey, to take charge of a compilation and digest of information on the water resources, particularly for military purposes, of the entire border part of the United States except the Canadian border, and the work was done in collaboration with a number of geologists and some engineers.

After the United States entered the war, time spent in supplying information to army and navy officials in compliance with requests received by the United States Geological Survey. The subjects included:

a) Information on water supplies for cantonments and other kinds of military and naval establishments.

b) Data on road building material and material for other structural purposes.

c) Studies of the nature of foundations of different kinds of structures.

d) Assistance in the selection of sites for several different kinds of military and naval establishments.

e) Data for use in compiling the progressive military map of the United States.

Robert DeC. Ward.

Gave instruction in Meteorology at the U. S. Army School of Military Aeronautics at the Mass. Institute of Technology, and, at the request of the Chief Signal Officer, prepared a manuscript on Meteorology in Relation to Military Aeronautics adapted for use at all the Army Schools.

At Harvard, gave regular courses in Meteorology, attended by members of the R. O. T. C. and of the S. A. T. C. Also, gave a special course in Marine Meteorology for members of the Naval Reserve, and special lectures to men enrolled in the Air Service program.

Published a series of a dozen articles on weather controls over military and naval operations during the war.

R. H. Whitbeck.

Volunteer instructor at the University of Wisconsin in the first Reserve Officers' Training Corps; also an instructor in the Student Army Training Corps.

Spent the summer of 1918 in Washington acting as Assistant Director of the Bureau of Research of the War Trade Board.

Bailey Willis.

In May, 1918 was appointed Chief of the Latin American Division of the "Inquiry." The work was carried on to March 1919, with a force which varied from three to twenty persons.

The investigation was of peculiar geographical interest. Thus the review of twenty odd boundary disputes involved geographical-historical research covering all of South America. A particular dispute between Uruguay and Argentina regarding jurisdiction over the waters of the La Plata, brought out the significant bearing of geographical facts on the legal questions involved in territorial waters as contrasted with high seas. The Tacna-Arica dispute between Chile and Peru led into a geographical study that went back to the days of Pizarro.

Another group of questions had to do with the resources of geo-

graphical districts and was based on topographical, meteorological, and botanical studies.

Ethnic research was required in the preparation of data on population, stage of culture, and capacity for self government. Engineering investigations were directed to the assembling of information as to trade routes, railway systems, built or strategically necessary water-powers, harbors, etc. Commercial relation formed another group, based also on geography.

Available maps having been found inadequate, a base map of all Latin America was prepared from original sources. It is on a scale of 1:2,000,000, or 32 miles to an inch and covers 29 sheets. It includes Mexico, Central America, the West Indies, and South America, from the Rio Grande to Cape Horn. The compiled data comprise drainage, political boundaries, railroads and roads, and places. The original draft of this map was sent to Paris, and an edition of 300 copies was printed for official use.

A draft of this map, reduced to 1:5,000,000 was also prepared.

TITLES AND ABSTRACTS OF PAPERS

BALTIMORE, 1918

Nevin M. Fenneman.

Presidential Address:—The Circumference of Geography. (Printed in full herewith.)

Wallace W. Atwood.

The Call for Geographers.

The war has emphasized the need of more trained geographers in America. The Army has called many into service, the Shipping Board has taken others. Some have been sent to France to act as experts; others have served in this country, either in the training of officers or in the organization of geographical data of special significance to the Army, the Navy, and the Department of State. The French and British nations have made similar demands upon their trained geographers. Some of the American colleges and universities have recently put in requests for trained geographers. There appears to be a great awakening in this country to an appreciation of the value of advanced studies in geography.

We are entering a period of maritime expansion. More men will be needed to go as representatives of great commercial houses in different parts of the world. Our Diplomatic Service will undoubtedly be increased. Those who attempt to represent us abroad should know the geography of this country, and should understand the influence of geographic conditions upon the peoples with whom they must deal. We must know better the peoples of the world, and to accomplish that we must know better the geography of the world. To improve the teaching of geography in this country opportunity must be given to those who teach the subject to know more than they are required to teach. Every college and every university in this land should open departments of geography or expand their present offerings in the science.

See, Geographical Review for January, 1919, pages 36-43.

O. E. Baker and H. M. Strong.

Arable Land in the United States.

The purpose of this paper is to describe the location and extent of present arable, non-arable and potentially arable land in the United States, with a view to providing those interested in land utilization with a broad, generalized conception of the subject.

"According to the best information, we have in all about 850,000,000 acres of land at present in crops and potentially available for the pro-

duction of crops. This is 45 per cent of the total land area of the United States, or about the same proportion the arable land of France is of the total area."

"Of these 850,000,000 acres nearly 480,000,000 acres were 'improved' in 1910. The remainder consists of about 200,000,000 acres of potentially arable forest and cutover land, of which probably more than one-half is at present included in the 190,000,000 acres of woodland in farms; 60,000,000 acres of swamps and other wet lands awaiting reclamation by drainage; 30,000,000 of potentially irrigable land; and about 80,000,000 acres of other lands, mostly 'unimproved land other than woodland' in eastern farms and dry-farming land in the west."

"These undeveloped lands may provide eventually about 3,000,000 farms, an increase of somewhat less than 50 per cent over the number of farms in the United States to-day. But unquestionably the better and the best land which it has been possible to develop by individual effort is now 'improved' land in farms, and much of that which remains undeveloped must await the gradual application of large amounts of capital to its development."

"The 1,000,000,000 acres of more or less non-arable land consists of about 360,000,000 acres of absolute forest land; that is land not adapted to crops but where climatic conditions permit the growth of forests; 615,000,000 acres of grazing land, practically all in the western States; and 40,000,000 acres of absolute desert land. In addition there are about 40,000,000 acres of land at present in cities, rural highways and railroad rights of way, an amount which will gradually be added to with increasing population. (See, Yearbook of the Department of Agriculture, 1918, pages 433-441, 10 plates.)"

Chas. F. Brooks.

Ocean Temperatures in Long-range Forecasting.

The slow, and more or less persistent changes in the temperature of the ocean waters over extensive areas, or in ocean currents, suggests the desirability of making a systematic study of temperature variations in connection with subsequent changes over adjacent land areas.

If it is possible (1) to forecast the distribution of surface water temperature a few weeks in advance, it may prove possible (2) to forecast the general paths which will be followed by cyclones and anticyclones, and then (3) from the winds which will result, to make long-range forecasts of the general weather to be expected in any period. (See, Monthly Weather Review for November, 1918, pages 510-512.)

William Churchill.

The Colonies, late German, in the Pacific.

G. E. Condra.

Potash a Factor in Winning the War.

(See: Final Report of the Nebraska Conservation and Soil Survey, 1919, on "Potash in Nebraska.")

Henry C. Cowles.

The Present and Past Climates of our Leading Crop Plants.

There are three great centers of origin of the major crop plants: Indo-Malaysia, Tropical America, and the Levant. Indo-Malaysia and Tropical America have given rise to most of the tropical crop plants; most of these derivatives have their major cultivation in the Tropics, though maize is a conspicuous exception to this. The plants derived from the warm temperate Levant, however, are the great crop plants of the cold temperate zones, and their present Levantine cultivation is decidedly of minor importance. The great staple crops of northern Eurasia, the United States, Argentina, South Africa, and Australia are not of native, but of Levantine origin. For this strange situation at least five theoretically possible reasons may be cited: (1) Gradual century-long acclimatization. (2) the origin, by mutation, of cold temperate races. (3) Climatic changes during the period of human culture. (4) The fact that species are not necessarily best suited to their place of origin. (5) Agricultural extension is possible without acclimatization.

William Morris Davis.

Work of the Geography Committee of the National Research Council.

Physiographic Evidence for Subsidence of Reef-encircled Islands.

Richard E. Dodge.

Some Aspects of the Food Problem—Read by Title.

The food needs of our Allies and of the increased populations in war industry centers, made necessary sudden, and in some cases revolutionary and confusing, changes in the food production program in our eastern states. Sections previously interdependent for necessary food products and farm supplies were suddenly thrown largely on their own resources and were obliged to alter their agricultual practices accordingly.

The farmer today must face increased costs of all essentials, new market needs and demands, a decreased supply of available labor, and the necessity of using new types of labor. Every condition affecting his work has changed.

Chas. R. Dryer.

The Maumee-Wabash Waterway (Printed in full herewith).

F. V. Emerson.

The Southern Longleaf Pine Belt.

"The Southern Longleaf Pine Belt is one of the most available regions for development in farms for returning soldiers. It includes an area nearly four times that of New York. Probably a third of the region has now been cut over and an area nearly equal to that of Massachusetts is being cut over each year. These lands have the advantage of present availability in a short time and without great expense; they are fairly near to markets and the climate is favorable. However they must usually be cleared of stumps, brush and undergrowth and the soils have relatively low fertility. These lands are readily adapted to grazing, less easily to truck and crops. A portion should be reforested."

(See, Geographical Review for February, 1919, pages 81-90, illustr.)

Herbert E. Gregory.

Geography in the Work of the Students Army Training Corps.
Organization of Geographic Instruction in the Universities.

Roland M. Harper.

A Statistical Study of New England Geography.

Alfred J. Henry.

Increase of Precipitation with Altitude.

Summary:—The main features of the precipitation-altitude relation are essentially as follows:

1. The trend of the mountains must be in such a direction as to cause an ascent of the air masses which encounter them. Mountain systems whose axes are parallel, or nearly so, with the direction of the rain winds cause little or no increase in precipitation.

2. The inclination of the slope of the mountain is of great importance; the steeper the slope, other things being equal, the greater the precipitation. The quantity of rain or snow which falls anywhere is also conditioned upon the initial temperature and relative humidity of the air at the beginning of the ascent. Obviously it also depends in no small degree upon the duration of the winds from the rain quarter, or upon the rate of movement of the atmospheric disturbance with which the rain winds are associated.

3. The altitude of the zone of maximum precipitation appears to vary slightly with latitude, being lowest in the tropics—a little less than 1000 meters—and highest in the temperate latitudes between

1400 m. and 1500 m. elevation. It has also a seasonal variation, being highest in summer and lowest in winter. (See, Monthly Weather Review for January, 1919, pages 33-41.)

Edmund Otis Hovey.

Geographical Notes on the Greenland Coast from Melville Bay to Etah.

Melville Bay presents an almost continuous ice front formed by glaciers and tongues coming down to sea level from the Inland Ice Cap. The principal breaks in this 300-mile wall of ice are Red Head, Cape Sedden, Cape Walker, Cape Murdock and Cape Melville. The islands paralleling the coast present no permanent ice cap. From Cape York northward the coast presents a fringe of bare land of varying width intersected by countless glaciers. These present all stages of development and are valuable for study.

Willis T. Lee (Introduced).

Notes on the Geography of the Rocky Mountain National Park, Colorado.

Douglas W. Johnson.

Geographical and Geological Work in the Allied and Enemy Armies.—Read by Title.

An account of the geographical and geological services rendered to the armies of our allies and to the German armies by experts in the two sciences.

C. F. Marbut.

Relation of Soil to Topography.

R. A. Millikan. (Introduced.)

Some Scientific Aspects of the Meteorological Work of the United States Army.

" There is no more interesting illustration of the application of new scientific methods to warfare than is furnished by the developments in meteorology during the Great War. Prior to 1914 a meteorological section was not considered a necessary part of the military service. No corrections had ever been made by the artillery of any army for any save surface winds. Firing by the map was almost unknown. No Sound-ranging Service, no Air Service, and no Anti-aircraft Artillery had ever existed to demand aerological data.

"At the time of the signing of the armistice on the western front the Air Service and all the artillery were being furnished every two hours with the temperature, air-density, wind speed and direction.

taken at the surface and at various altitudes from 100 to 500 meters apart, up to 5000 meters. Further, tables were prepared from which each battery could obtain the correction suited to its trajectory for the so-called ballistic wind. This is the average wind for the trajectory, weighted for the density of the air at the elevations traversed. Even machine guns when used for barrage work made use of these ballistic wind tables."

"In addition, daily forecasts were furnished to the armies in accordance with the following outline:

A. Character of weather for each arm of the surface.

B. Winds; At surface, at 2,000 meters elevation, at 5,000 meters.

C. Cloudiness, including fog and haze.

D. Height of clouds.

E. Visibility.

F. Rain and snow.

G. Temperature.

H. Warning of weather conditions favorable for use of gas by the enemy.

K. Probable accuracy, or odds in favor of the forecast."

"Most of the aerological data were obtained from theodolite observations on pilot balloons. The extent to which our knowledge of the upper air has been and is being extended by this pilot balloon work may be seen from the fact that before the war there existed but one station in the United States where pilot balloon observations were carried on regularly. Within a year of the inception of the meteorological service in the United States Army, 37 complete stations for the obtaining of both surface and upper-air data in aid of aviation and the artillery had been established in the United States and equipped with special aircraft theodolites and pilot balloons, neither of which had ever been produced before in this country. Further, 20 such stations had been established by our forces abroad. For the manning of this service, about 500 specially selected men had been trained in this country, and 314 of them sent abroad, while about 200 were held for work in the United States."

"The scientific interest in this service centers about four distinct problems:

1. The extension of our knowledge of the law of motion of pilot balloons.

2. The procurement of data and the development of methods for the preparation of artillery range tables.

3. The development of long-range propaganda balloons.

4. The charting of the upper-air in the United States and overseas in aid of aviation."

(See, Monthly Weather Review for April 1919, pages 210-215.)

Frederick Morris. (Introduced.)

The Terrain and the War in Italy.

A brief account of the Terrain in general introduces the subject. The Plain of Northeastern Italy presents two aspects, a Piedmont belt of confluent alluvial cones with braided rivers, and a lower more richly watered and more densely peopled shoreward region. Along the coast the swampy delta lands with their network of canals and canalized streams formed a third aspect presenting special military problems.

The mountains rise abruptly above the plain, and present in general a twofold aspect that has profoundly conditioned the military operations. Along the southern edge of the great upland is a fringe of unglaciated "plateaus," cut by youthful river canyons. Behind these lies a sea of alpine peaks and long chains of arêtes. Enormous glacial gorges cut through the glaciated and unglaciated regions, reaching to the plain in some cases, in others, as in the Isonzo below the Tolmino basin, changing to typical V-shaped youthful valleys. The broadly rounded unglaciated mountains, such as Asolone, Grappa, Tomba, Baldo, Valbella, admit of larger movements of troops and artillery than is possible on the Alpine peaks, so that the defence of this unglaciated fringe of hills has more nearly resembled that of the French at Verdun than has any other fighting on the Italian front.

The elevated, undulating uplands called plateaus in the news despatches, such as the Lavarone, Folgaria, Asiago, Carso, Bainsizza, had yet other problems for the armies engaged across them.

The events of the war were analyzed by the author in their relation to the topography and geology of the region.

Ellen C. Semple.

Geographic and Climatic Factors in the Ancient Mediterranean Lumber Trade. (Printed in full herewith.)

The Ancient Piedmont Route of Northern Mesopotamia.

Eugene Wesley Shaw.

The So-called Lakes of the New Madrid Earthquake Area.

It is generally supposed that numerous rather extensive tracts in southeastern Missouri and northeast Arkansas subsided at the time of the New Madrid earthquake of 1811-12, and all maps of these states show many lakes and swamps. The tracts are widely known as "sunk lands."

As a matter of fact, however, there are few lakes, and even swampy conditions do not seem much more characteristic of the "sunk lands" than of intervening territory. This general fact has become more or less well known to the people living in the region and to others who have had occasion to travel through this heavily forested portion of the Mississippi bottom lands; but maps published in atlases and elsewhere have not yet been corrected.

Title to the lands represented as lakes hangs on the correctness of the original Government land survey made seventy or eighty years ago. If this survey was correct and the lakes have become filled or drained, their fertile beds must now be parceled out among those owning bordering lands—the riparian claimants. If however the old surveys were erroneous the lands are now, it is claimed, the property of the nation and open to homestead. H. C. Cowles, as ecologist, and the writer as a student of sediments and surface features, have been called upon at various times to testify as to whether certain "lakes" or groups of "lakes" have been lakes within the period involved. Notwithstanding the fact that the lands are all subject to overflow it has been possible to gather convincing evidence that the old land surveys were erroneous so far as the lakes are concerned.

Thomas Wayland Vaughan.

Some Features of the Virgin Islands of the United States.

The name Virgin Islands seems not to apply to a natural group, for it is applied, first, to the islands that lie between the east end of Porto Rico and Anegada Passage and rise above the shallow Virgin Bank, which is really only an eastward, slightly and recently submerged extension of Porto Rico and is bounded by deep water on its northern, eastern, and southern sides. If the Virgin Islands included only the protuberances above the surface of this bank, the name would seem logical enough, but when they include Saint Croix, which is separated on the south from the Virgin Bank by water 2,400 fathoms deep, there appears to be no geographic unity in the group. However, at a time geologically not long ago no oceanic abyss separated Saint Croix from Porto Rico and the Virgin Bank, and then they all formed a part of a natural group.

The relations of the Virgin Islands to the principal Caribbean ridges and deeps.

There are two roughly east and west main Caribbean ridges. The first is the Cuban ridge and the second is the Rosalind Bank—Jamaican ridge. The Cuban ridge, notwithstanding its interruption by the Windward Passage, is continued into northern Haiti; while the Rosalind

Bank—Jamaican ridge is prolonged into southern Haiti. These prominent tectonic features converge in Haiti. It would lead too far afield to attempt a more special account of these relations in this connection, but they are not so simple as might be inferred from the statement just made. Porto Rico is on a bank extending eastward from Haiti, from which it is separated by water having a maximum depth of 318 fathoms in Mona Passage. Virgin Bank, as has been stated, is only a slightly submerged part of Porto Rico.

The principal deeps of the Caribbean region are Bartlett and Brownson deeps, but there is relatively deep water on the two sides of the important ridges, and the water in both Windward and Angada passages is 1,000 fathoms in depth.

The other Caribbean ridges are the Barbadian Ridge, the Main Caribbean Arc, with the two prongs of its more northern part, and Aves Ridge. The Main Caribbean arc terminates at the north at Anegada Passage.

Saint Croix is connected by shallower water with the Saint Christopher Chain than any other islands and might on this ground be considered as naturally forming a part of the inner prong of the Caribbean Arc, but its geologic kinship is with Saint Thomas and Porto Rico.

Islands of the Virgin Bank.

There are about 100 of these islands, and needless to say no such number of islands can be described in this brief statement. They were discovered by Columbus during his second voyage in 1493, and had a more or less thrilling history during the buccaneer days prior to 1666, when Tortola, Virgin Gorda, and Anegada came into the possession of the British. The Danes colonized Saint Thomas and Saint John in 1672; and the Dutch settled in Saint Croix in 1643. The possession of the Virgin Islands is now divided between the United States and Great Britain. The United States has dominion over the islands between Porto Rico and the Virgin Passage and over Saint Thomas and Saint John; while the British islands, about 32 in number, include Virgin Gorda, Tortola, and Anegada.

Except Anegada, which is composed of limestone and rises only 30 feet above sea level, the islands on the Virgin Bank are high and rocky. The peaks on some of the different islands attain heights as follows: Saint Thomas, 1,500 to 1,550 feet; Saint John, 1,270; Jost Van Dyke, 1,070; Tortola, 1,780; Virgin Gorda, 1,370. The summits of the peaks therefore range from about 1,000 to about 1,800 feet in altitude. The material composing the islands is largely of basic igneous rocks (andesite and andesitic tuff and agglomerate) but there are some

sediments and Cleve collected Cretaceous fossils in these on Saint Thomas. They are not composed of coral rock. The land areas have been well dissected by erosion and they are bordered by typical shore lines of submergence. The sea bottom is terraced in a most interesting way, as the charts and profiles based upon the charts show. This is a famous coral-reef region, the growth of certain species of corals being the most luxuriant known. As I have discussed in several papers the conditions under which the reefs of the Virgin Bank formed, I need not say anything special on them in this place.

The harbors of Charlotte Amalia, St. Thomas, the Coral Bay, Saint John, are both good, but that of Charlotte Amalia is exposed on the south and may be raked by hurricanes, while Coral Bay is protected on all sides.

Saint John, an irregularly shaped, narrow island, 8 miles long, is forested, and bay leaves, used in the manufacture of bay rum, are gathered there. Its soil is said to be fertile, and in the days gone-by coffee, sugar, and tobacco were produced, but at present cattle raising is the principal industry. In both Saint John and Saint Thomas there has been lack of labor to cultivate the small areas of arable land on them. Saint Thomas, which is 12 miles long and 3 miles wide, has lost the importance it once enjoyed as a port of call for vessels, because of a combination of circumstances, one of which was the laying of submarine cables. However, it is still an important coaling station, and the floating docks are used for repairing disabled ships. It appears to me probable that sea-island cotton, which is profitably cultivated on many of the islands farther south, might be grown on some tracts of land. The population is almost entirely black or colored—there were in 1917 about 960 inhabitants on Saint John and about 10,190 on Saint Thomas. The white houses with red-tiled roofs, arranged on the sloping sides of the hills that rise above Charlotte Amalia Harbor, are very attractive, and I wish that I might dwell on their charm.

Saint Croix.

Saint Croix, which was at first named Santa Cruz, was another of the islands discovered by Columbus on his second voyage in 1493. It is about 40 sea miles nearly due south of Saint Thomas on the other side of one of the most remarkable abysses in the world. According to the hydrographic chart the ascent from the sea floor north of Saint Croix in places is at an angle of as much as 70 degrees. There is an ascent of 13,656 feet within a horizontal distance of 25,800 feet. As the west end of the island is approached from Saint Thomas, the steep

north coast is most impressive—it is one of the finest known examples of a fault shore line—the faulting having taken place so short a time ago that the sea has barely cut a niche into the fault plane. In fact, the rather frequent violent earthquakes in this locality show that fault movement is still taking place.

There are two dominant geologic formations in Saint Croix, namely: One of older, tightly folded rocks, composed partly of Cretaceous sediments and partly of igneous rocks, which occur in the northern part of the western half, constitute most of the eastern half of the island. The higher hills are composed of these rocks. The other rocks are gently tilted limestones, that form a plain sloping southward from the well-dissected northern hills of the western half of the island and at a place a little west of Christiansted extend through a gap in the hills and reach the north shore. This limestone is not coral work, for corals are a very minor constituent of it. The hills represent a stage of mature dissection and range in altitude from about 800 to 1,164 feet, the latter figure being the height of Mount Eagle, the highest summit on the island. The shore line is indented by arms of the sea and is a good example of a shore line of submergence. Barrier coral reefs are well developed at several places off the shore, but it is interesting to note that there is no barrier reef where the shore follows the line of a steep fault plane.

I have indicated in preceding remarks that there is similarity in the older geologic formations (the Cretaceous) of Saint Croix and Saint Thomas, and that the abyss separating Saint Thomas and Saint Croix is the result of faulting of a geologically late date. The abyss just mentioned is prolonged into Anegada Passage. A continually increasing volume of biogeographic data seems to demand land connection from Porto Rico to Anguilla and to Saint Croix during either Miocene or Pliocene time, and that Saint Croix and the islands of the Virgin Bank then formed part of one land area, which has been broken into separate masses by block faulting. Although now dissevered, there was a time when Saint Croix was not isolated from its kindred islands some 40 miles farther north.

Christiansted, the capital of the island, had in 1917 a population of 4,574, while the population of Frederiksted was at that time 3,144. The total population of St. Croix is about 14,900, mostly negroes or colored people. A large proportion of the land on the island is arable and fertile. The principal industry is raising sugar cane, from which sugar and rum are made, but some attention is now paid to sea-island cotton.

I wish that I might say more about these islands, for they possess

many interesting and delightful features. Under ordinary conditions, they are all easily accessible from New York, and I am confident that those who may visit them will find pleasure and scientific profit in the excursion.

Bibliography.

The following are some of the more important references to literature on the geography of the Virgin Islands:

British Admiralty, West India Pilot, vol. 2, 6th ed., pp. 298-355, London, 1909.

Cleve, P. T., On the Geology of the Northeastern West India Islands: Kongl. Svensk. Vetensk. Akad. Handl., vol. 9, No. 12, pp. 48, 2 maps, 1871.

Hartley, Eugene F., Census of the Virgin Islands of the United States, Nov. 1, 1917: Bur. of the Census, Dept. of Commerce, pp. 174, 15 figs., 1918.

Hill, Robert T., Pelé and the Evolution of the Windward Archipelago: Geol. Soc. Amer. Bull., vol. 16, pp. 243-288, pls. 43-47, 1905.

Quin, John T., The Building of an Island, being a Sketch of the Geological Structure of the Danish West Indian Island of Santa Croix, or Santa Cruz, pp. 106, 1 Map, 32 text figs. Published by the author, Christiansted, Saint Croix, 1907, (This is a memoir of very great value.)

Taylor, Chas. Edwin, Leaflets from the Danish West Indies, pp. 228, illustrated by numerous unnumbered wood-cuts. Published by the author, at Saint Thomas, Danish West Indies, 1888.

Vaughan, T. W., Some Littoral and Sublittoral Physiographic Features of the Virgin and Northern Leeward Islands and their Bearing on the Coral Reef Problem. Washington Acad. Sci. Jour., vol. 6, pp. 53-66, 1916.

Vaughan, T. W., Fossil Corals from Central America, Cuba, and Porto Rico, with an Account of the American Tertiary, Pleistocene, and Recent Coral Reefs: U. S. Nat. Mus. Bull. 103, pp. 180-524, pls. 68-152, text figs. 4-25, 1919.

Vaughan, T. W., The Biologic Character and Geologic Correlation of the Sedimentary Formations of Panama in their Relation to the Geologic History of Central America and the West Indies: *Ibid.*, pp. 547-612, 1919.

Lists of the hydrographic charts for the Virgin Islands are contained in the catalogues issued by the United States Hydrographic Office and the British Admiralty. Prof. Oliver L. Fassig has in preparation a report on the climatology of the islands.

Robert DeC. Ward.

Rainy Days and Rain Probability in the United States.

The diagram of geographical distribution of rainy days shows over 100 rainy days per year east of the Mississippi River, with a maximum area of 170 days in the Lake region. West of the Mississippi the frequency varies from a minimum of 20 per cent in the arid southwest to over 80 in the Rocky Mountain District. In a narrow band along the extreme northwest coast the annual frequency attains an average value of from 120 to 180 rainy days. (See Geographical Review for January 1919, pages 44-48.)

ABSTRACTS OF PAPERS

Read at the Joint Session of the Association of American Geographers and the Geological Society of America, 1918.

J. W. Bagley and Fred H. Moffit (Introduced).

A Method of Aerial Photo-Topographic Mapping.

The construction of maps from photographs has been practiced for many years but the use of air plane photographs for this purpose did not become practicable till after the outbreak of the present war when the necessities of the operations on the different battle fronts led to very extensive use of air plane photography for this purpose. Nearly all the maps so far constructed consist of single photographs having a narrow angle of view and therefore covering only a small field. The photographs are taken in a more or less unsystematic way and are joined together without corrections for errors other than that of scale. These maps are commonly called "mosaics."

In order to increase the speed of working and decrease the cost of the map as well as to carry out the work in a better and more systematic way, a multiple camera with inclined plates has been designed so that three overlapping photographs covering a large field may be taken simultaneously. Deviation of the plates from a horizontal position, due either to the attitude of the air plane or to the construction of the air plane camera, introduces errors of distortion so that the photographs are not true maps of the areas covered. These errors are corrected by projecting the negative photographically on a horizontal plane in accordance with principles first described by an Austrian army engineer, Capt. Theodore Scheimpflug. The photographs are then brought to the desired scale and joined together to form the map. Special cameras for correcting the errors mentioned have been designed and are now in use by the Corps of Army Engineers, but much remains to be done before the method is perfected.

Albert Perry Brigham.

Principles in the Determination of Boundaries.

Discusses physical boundaries and human factors in boundary making, and arrives at the following conclusions:

The present arrangement of human groups is a heritage from long existing biological conditions of dispersal, migration, and intermingling, complicated by the vagaries of the human will, as seen in lust of conquest, love of war, dynastic ambitions, and economic greed.

The necessity of boundary lines has come with the filling of the world's spaces, the pressure of population on resources, and the lifting and widening of the material standards of living.

We hold with Lyde that civilization is "progress in the art of living together." Any nation is backward in civilization in proportion as its standards of international dealing fall below its laws of intra-national conduct.

We do not accept Holdich's virtual admission that international ethics are permanently so low that defensive boundaries will always be essential to reasonable safety against attack.

On the other hand we are not convinced that boundaries should be deliberately and always placed where people meet. We would not avoid such lines if the greater justice to the greater number on both sides of the proposed fence seems to require them. We might for the present give questionable or quarrelsome neighbors as high a fence as is practicable, as we try to keep the weak of all sorts from overpressing temptation.

Approximately twenty-five human groups in Europe show such unity of purpose and ideal, such community of interest, of history and of hopes, and each in such reasonable numbers, that they have embarked or deserve to embark on a career of nationality.

The world is now pretty well agreed that ruling houses are obsolete, that the interests of great powers are no more valid than those of small powers, and that economic equilibrium or self sufficiency in natural resources does not outweigh the rights and desires of any truly national group.

Europe has an exceptional number of physical units which in primitive days could serve as the cradles of nations. In the advanced conditions and high densities of today, however, the number of physical compartments falls far short of the number of groups which properly wish independence.

Modern appliances for war have impaired the security once gained through physical barriers. Heights of land and all kinds of waters give important aid in war, but they do not fend off war. We cannot destroy the germs of frontier dispute by drawing physical boundaries."

We must draw boundaries on defensible or separating lines if possible but at all events in such a way as to work substantial justice.

Here is the sphere of a league of nations, embodying the will of all mature civilization that imperfectly civilized groups shall no longer make biological inferences or blasphemous conceptions of divine destiny the excuse for perpetuating tooth-and-claw methods in the relations of peoples. (See Geographical Review for April, 1919, pages 201-219.)

M. R. Campbell.

Geographic Descriptions of Army Cantonments and of United States Boundary Regions.—Read by Title.

Oliver L. Fassig.

The Signal Service School of Meteorology.

In the fall of 1917 a Meteorological Division of the Signal Corps of the Army was formed under the supervision of the Science and Research Department in co-operation with the U. S. Weather Bureau. About 200 men mostly drawn from our colleges received two months' special training as weather observers at selected stations of the Weather Bureau.

In the spring of 1918 a special school for this training was established at the Agricultural and Mechanical College of Texas, at College Station. The instruction staff consisted of the writer as Chief Instructor, Dr. Chas. F. Brooks of Yale University, Lt. W. S. Bowen of the Signal Corps, and Mr. W. T. Lathrop of the Weather Bureau, as Assistant Instructors. The military instruction and drill were given by the Commanding Officer of the Meteorological Division, Lt. H. B. Hovde and his staff.

The class consisted of 300 men, mostly civil, mechanical and electrical engineers, and instructors in physics, chemistry and mathematics, including about forty men with previous training in the Weather Bureau.

The daily schedule of technical studies included the following:

1. A lecture on general meteorology or aerology.
2. Frequent cloud studies in the field.
3. The construction and interpretation of the daily weather map based upon daily telegraphic observations from 75 Weather Bureau stations.
4. Daily observations such as are made at all first order stations of the Weather Bureau.
5. The preparation of meteorological forms.
6. Thorough and practical field instruction in the use of the theodolite for determining the paths of small rubber balloons which were filled with hydrogen and liberated. These balloons indicated the varying directions and velocities of the atmospheric currents to heights of many miles above the surface of the earth.

The high grade of men composing the class made it possible to develop many new mechanical devices and quick methods for reducing observations for determining the ballistic wind in the correction of long range artillery fire. The projectiles fired from the large modern guns not only have a range exceeding 20 miles, but they are carried to elevations of 10 or more miles above the earth's surface—into regions where the wind velocities and directions differ widely from those prevailing at the surface.

An intimate knowledge of the temperature and density of the air and of wind velocities and directions, is indispensable in attaining

accuracy in long range artillery fire, and in anti-aircraft operations, in charting upper air currents for commercial aviation, and in selecting safe landing places for the aviator of the future.

At the time of the signing of the armistice about 500 men had been given special training as weather observers in the Signal Corps of the Army, for a period of from two to three months. About 300 of these men were sent overseas, and about 200 were retained in this country and assigned to duty at a score or more of the flying and artillery fields, at ordnance camps, balloon schools, and with radio detachments for the purpose of supplying these branches of the Army with the meteorological information desired by them. Twenty-five of the men of the School were transferred to the New London Naval Station for further instruction in connection with the development of the hydrophone, an instrument designed to detect the presence and locate the position of submarines.

(See Monthly Weather Review for December, 1918, pages 560 to 562.)

C. K. Leith.

Internationalization of Mineral Resources.—Read by Title.

F. E. Matthes.

The American Topographer in the Rôle of Artillery Orientation Officer.

When the United States went into the war its artillery arm possessed practically no trained artillery orientation officers, and was not prepared to execute long range artillery fire of the kind that has played so important a part in this war. Civilian topographers, mostly from the Geological Survey, were trained for this work by French officers and were found to be particularly well fitted for it by reason of their previous training in topographic survey methods. In a few months they became expert enough to hold their own against the highly trained artillerists of the enemy.

The principles of modern artillery orientation were outlined and examples of plane table and other surveys were sketched upon a blackboard.

Eugene Wesley Shaw.

Mexican Petroleum and the War.

The part played by petroleum and its products in the great war is a subject of general discussion, but there seems to be agreement that this

part was very essential both in comparison with other war minerals and in comparison with other elements that contributed toward success. The value of Mexican petroleum involves peculiar factors, though like the value of other available oil supplies, it has been controlled mainly by quantity, quality and accessibility.

The quantity factor has had the following outstanding features: The country is the third largest producer in the world and furnishes roughly one-tenth of the total supply. Eight years ago the output of the country was scarcely one-twentieth as great as in 1918 and the fraction of the world's output was only about one per cent. Twenty years ago the pools were undiscovered. On the other hand the aggregate capacity of the wells already drilled has differed from those of other regions in that it has always been far above the actual output; also if conditions of development had been as favorable as they are in some parts of the world there would have been many more wells drilled and a far greater supply of oil would have been available—perhaps twice as much as all the world is now producing. The country has the largest oil wells in the world and the main part of the output has come from a very few wells. Roughly, half of the output of the country in 1918 was used in connection with the domestic and military requirements of the United States, and of the capital invested in Mexican oil nearly two-thirds is American.

As to quality, the peculiar features of Mexican petroleum lie in the relatively low percentage of light distillates and the relatively high sulphur content. It furnishes little gasoline in comparison with its bulk, and this percentage has not been raised to a high figure through cracking processes. However, Mexico offers an immense reserve of fuel oil, though for fuel much of the oil needs an admixture of more fluid oil, or special burners adapted to its high viscosity. Its percentage of undesirable sulphur is reduced most readily by the addition of sulphur-free oil.

The accessibility depends on many considerations, including its distance from the points where it is refined and used and from the sources of labor and supplies, upon the tankers, pipe lines and other transportation facilities available, and upon political conditions in and around the fields, arising out of local disturbances and the decrees issued by the Mexican Government, involving high taxation (15 to 20 per cent.) or nationalization, or threatened "confiscation of private property, and arbitrary deprivation of vested rights." The area in which the fields are located is small relative to the quantity produced, and it borders on the sea. If sufficient tankers had been available, the production for 1918 would have been five to ten times greater.

Glenn S. Smith (Introduced).

American Mapping in France.

Organization for topographic work in American Expeditionary Force. Magnitude of job undertaken and necessity for special speed. Opportunity to test American methods in comparison with those of the British and French.

Joseph B. Umpleby.

World View of Mineral Wealth.

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GENETIC GEOGRAPHY

The Development of the Geographic Sense and Concept*

CHARLES REDWAY DRYER

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INTRODUCTION: THE NEW STATUS OF GEOGRAPHERS.—Before entering upon the special theme of this address, I wish to note briefly some recent changes in the status of our science and our Association. The late war has taught the world, among other things, that geography is one of the sciences which have a practical bearing upon the largest affairs of the world. Perhaps for the first time in history, geographers have been summoned to the councils of the nation to perform duties which only men with geographical training can perform. Almost every member of our Association has served in some capacity and the details of their war service will be recorded in the forthcoming volume of our Annals. A large number of our members took part in "the Inquiry," conducted by request of President Wilson, under the auspices of the American Geographical Society, in preparation for the peace negotiations, and several of them have served on the expert staff of the Peace Commission at Paris. Others have rendered invaluable service at Washington, and one result is the appearance of new titles and honors, which seem strange in a list of geographers. We may now salute and address, Lieutenant Colonel Brooks, Major Johnson, Major Martin, Captain Huntington, Captain Cushing and others of equal rank. I think all have resumed their peaceful duties except Major Martin, who is geographer to the American Mission to Armenia.

* Presidential address before the Association of American Geographers, St. Louis meeting, December, 1919.

On the National Research Council, which has been made a permanent and official part of the Federal Government, our Association has three representatives. Out of twenty-one members of the Division of Geology and Geography, eleven are members of the Association of American Geographers, viz,: Messrs. Blackwelder, Bowman, Brooks, Davis, Fenneman, Gregory, Grosvenor, Huntington, Johnson, Smith and Vaughan. Geography seems to be coming into its own and to have acquired a better standing among sciences and in the councils of the world.

The Geographic Sense in Animals.—I shall take as a starting point for our flight into space two contrasted statements about geography. The first is that of a boy who said that the earth is a ball filled inside with dirt and worms and covered all over on the outside with nothing but geography. The second is a saying of the very eminent geographer who is also a member of Parliament to the effect that geography is not a science but a state of mind. The common element in the mind of the boy and of the geographer seems to me to be consciousness of his surroundings. Each knows, to use our western phrase, "where he is at."

The sense of locality is shared by many animals and in some is highly specialized. Bees seem to have an unerring sense of the direction and distance of the flowering plants within a few miles of the hive. A squirrel with a nest in a hollow tree acquires an intimate knowledge of the location of the nut-bearing trees in the vicinity and of the arboreal routes leading to and from them. Similar statements may be made about foxes, bears, wolves and other animals. In birds the instinct of locality attains continental dimensions and lies beyond the scope of our understanding or imagination. Millions of them migrate annually, not only between Florida and Hudson bay, but between Alaska and Cape Horn. Somehow they are guided from the home of one season to that of the next through thousands of miles over land and sea. To an inlander the strongest impression made by the sea is its homelessness, its negation of differentiation in space. All landmarks which distinguish one spot from another disappear. One seems to be launched into a spaceless universe and knows or cares where he is no more than the porpoises that follow the ship. Yet the fur seal may be trusted to circumnavigate the North Pacific and turn up on time at the breeding grounds of the Pribilof islands. There is nothing in nature more miraculous than the home coming of the salmon, after years of oceanic wandering, up the Columbia to the lakes of Idaho, where they were born.

The Geographic Sense in Primitive Man.—Primitive and savage men are compelled by their desire for food, shelter, safety and offspring to become intimately acquainted with some portion of the face of the

earth and to acquire a knowledge, definite and detailed as far as it goes, of their environment. It is this awareness of environment in animals and men which I call the geographic sense, primarily a sense of space relation with external objects, but developing inevitably into a sense of other and more complex relations. The geographic sense even has its special organs, located in the semicircular canals of the middle ear. These are the organs of orientation by which we are sensible of our own position in relation to our environment. We are ordinarily unconscious of their function, but the importance of these organs is appreciated when we experience the discomfort and confusion of being "turned around," which may amount in the case of a person who "gets lost" to a dangerous species of insanity.

The Geographic Sense in Children.—There is no better place to study the development of the geographic sense than in our own homes, provided that the family includes normal children. An active child spends most of his waking hours exploring his environment, in finding out what there is in it and what use he can make of everything he finds. In his world of the nursery it does not take him long to find the shortest road to the toy box, the picture book and the candy jar. Some spring morning, after he has learned to walk, he is turned out of doors and his world suddenly expands enormously. He plunges into its exploration with more zest than Columbus or Magellan ever knew, and every day makes discoveries more important to him than the gold of Peru or the spices of the Indies. And so on, throughout the period of childhood and youth, the human animal continues to expand his consciousness of environment, to learn where things are and the way to get at them. He thus acquires an empirical knowledge of geography more thorough and durable than teachers and textbooks can furnish.

Some writers on pedagogy maintain that the only distinctive geographical discipline consists in the development of this geographic sense, in making it more exact and comprehensive and expressing it in proper symbols; in the reduction to graphic terms of the general consciousness of location, direction, distance, dimensions and contents in space; in short, areal distribution as finally expressed on a map. Pure empirical geography becomes highly developed in some occupations, as in the case of sailors, postal clerks and commercial travelers.

The Fundamental Concept of Geography.—You meet a man in the street who knows that you have some reputation as a geographer, and he asks you what he conceives to be pertinent questions about Poland or Roumania or Japan. Where is it? How big is it? What is there in it? How do you get there? Such questions indicate possession of the geographic sense and represent a geographical state of mind which is perfectly correct as far as it goes. It seems clear

and beyond question that the psychological foundation of the geographic concept is the sense of distribution in terrestrial space. We must concede the pertinence of the doctrine of Kant that "geography is a narration of occurrences which are coexistent in space."[1] This idea, more sharply put by Bain in the statement that "the foundation of geography is the conception of occupied space,"[2] fits and includes every work generally recognized as geography from Strabo to Ritter and Reclus. With various additions and qualifications, it forms the essence of most of the current and accepted definitions of geography, of which quotation is unnecessary.

Distribution, Static and Dynamic.—Assuming then that the logical and historical core of geography is distribution, the question arises, distribution of what? The favorite term of the definitions referred to is *phenomena,* which would include anything and everything, physical and spiritual. A correspondent suggests that it would mean the distribution of fallen leaves in the forest and of grass blades on the lawn. And why not? It may be granted that a study of the fallen leaves is hardly worth while, yet who can tell? The botanists have been known to take a complete census of all the plants growing in a limited area. Even a study of the distribution of poetry books, musical instruments and works of art is not so absurd as its proposers meant to imply. It might disclose some interesting relation in human geography, including a response to physiographic control. The distribution of ideas and emotions is as truly a part of geography as that of rainfall or corn crops. A map showing in shades of color the prevalence of a belief in transmigration, in the infallibility of the Pope, in the divine right of kings, or any other dogma, doctrine or notion, would be a valuable contribution to human geography. The story of the garden of Eden, which Sir William Willcocks has definitely located,[3] including the tree of life, the serpent, the apple and the fall of man, which forms the basis of the current Christian philosophy, is as characteristic of the physiographic conditions of Mesopotamia as the date palm. Such a story and such a system could not have originated in northwestern Europe, in eastern North America or in the Amazon basin. To determine whether a given problem is geographical or not is easy. The question whether its study is worth while will be answered according to individual judgment and bias.

The Causal Idea in Distribution.—No geographer nowadays is content with a mere knowledge of static distribution in space. The scientific spirit impels him toward the dynamics of distribution, to supplement the questions, Where is it? How big is it? What does it

[1] Immanuel Kant, Physische Geographie, Königsberg, 1802, pp. 1-20.

[2] Alexander Bain, Education as a Science, p. 272.

[3] *Geographical Journal,* Vol. 35, p. 1.

contain? with the more significant question, How came it to be where it is? An inquiry into the causes of distribution gives geography an entirely different aspect and opens the door to relations more comprehensive than those of space. When description of the earth becomes explanatory description no pertinent consideration can be shut out. The causal or scientific element has never been wholly absent from geography. Herodotus, who was as much geographer as historian, uses the method of multiple hypotheses in an attempt to account for the overflow of the Nile[4] and Strabo ascribes the presence of sea shells on land to elevation from the sea bottom.

Influence of Geology.—Scientific geography survived the dark ages in a state of hibernation. It was revived in the 18th century to be nearly swamped in the cosmic schemes of Humboldt. At the middle of the 19th century, under the hidebound teleology of Ritter and Guyot, it was in danger of arrested development and senile decay. From such a fate it was saved by a transfusion of blood and vigor from the young science of geology, which has sprung up by its side, free and comparatively unhampered by tradition. One result of geological training was a demonstration of the futility of Guyot's laws of relief and other empirical schemes, and the organization of the science of land forms, with which the name of the godfather of this Association is so closely connected. It is not too much to say that this was the most effective contribution to scientific geography ever made, and its far reaching results are too well known to be dwelt upon here. Through it, geography was brought for the first time into the quickening stream of modern scientific thought.

Influence of Biology.—In the meantime the Darwinian leaven was revolutionizing not only biology but human thought, and geography could not escape its influence. The distribution of plants and animals in relation to relief, soil and climate and their adaptation to all sorts of elements in their environment, opened a new and fascinating field of research, which was recognized as being of the very essence of geography. Ecology, defined by Haeckel as "the science treating of the reciprocal relations of organisms and the external world," came in to solve some of the most complex problems of biogeography. It was able to give at least a broad general answer to the question, How came this plant or this animal to be where it is? and to throw some light on the question, How came it to be what it is? As plants and animals have in some way become more or less completely adapted to their environments their existence in a given environment being in itself proof of sufficient adaptation to survive; so throughout the habitable world, men are consciously adapting themselves to varied environments. Their culture, or kind and grade of civilization, is

[4] Herodotus, History II, 19-27.

determined by the possibilities of the environment and by the ability with which they avail themselves of these possibilities. In the field of human adaptation the anthropologist, the sociologist, the economist and the historian are incidental students and make valuable contributions, but the man whose special business it is to cultivate this field is the anthropogeographer. The most notable geographic phrase that has appeared in the English language in the 20th century is "physiographic control and organic response," and the epochal books are devoted to the discussion of "the influences of geographic environment," for all of which our Association claims a large share of credit. After all that has been written about the fitting of man to his environment, a biological chemist turns the thesis around and shows an equal claim for the fitness of the environment.[5] This brings us again in sight of the position of Ritter, that each environment has been specially adapted to be the home of its human occupants, and to reintroduce into geographic philosophy a modified teleology.

Geographic Environment.—Through the whole range of geography, the empirical observation and record of the distribution of terrestrial phenomena in space are now supplemented by studies of explanatory relationships, which are found to exist between phenomena of the most diverse categories. In inorganic geography distribution remains the dominant note; in organic geography that note is drowned in the harmonies of adaptation. The effect of the whole concert is an increasing exaltation of the geographic sense. In our expanded and intensified consciousness of environment, the primitive elements of direction, distance and dimensions are absorbed in the concept of diversified contents. It is this condition which I believe Mr. Mackinder meant when he said that geography is a state of mind. When we have acquired the same kind of consciousness of the whole face of the earth that we have of our own home and neighborhood, we will have attained the geographic state of mind, and it will be the logical and psychological development of the mind of the child exploring his nursery and playground.

If we take environment as the key note of geography, the question at once arises sharply, how much of the environment? Must we take into account all its phases or only the physical or natural environment? In a study of Indiana as a geographic environment, the position of the state, its relief, drainage, soil, climate, vegetation, native animals and mineral resources, and the influence of each on the condition and character of the human inhabitants must be given serious consideration. But how much weight, if any, should be given to the fact that the population was orginally derived from two contrasted strains, one from the Carolinas and Virginia through Kentucky,

[5] Lawrence J. Henderson, The Fitness of the Environment, 1913.

and the other from New England, New York, and Pennsylvania through Ohio, each bringing its own peculiar political and religious opinions, social customs and vernacular speech? Are the flight of Quakers from slave holding communities and their influence on the political, religious and educational character of the Hoosier state facts of geography as well as facts of history? A conservative geographer might feel that the admission of purely psychological factors stultifies our name and title by leaving the *ge* out of geography. But as our planet shrinks in physical bulk, it expands in ideal content, the primitive γή, or solid earth, becomes the widest possible κόσμος, or world, and the geographer is forced to become a cosmographer. If he works around the central idea of distribution, he must not omit the distribution of the love of freedom, peace, plain clothes and plain language. If he works around the idea of environment, to ignore the psychological environment would reduce human geography to a headless torso. We have come to the point of admitting a new member to the set of concentric earth spheres and enclosing all in the psychosphere. If any one is troubled by doubts, he may console himself with the thought that any psychological phenomenon, when traced back far enough, may be found to be closely related to some conditions of physical environment. Geographers generally are prepared to give social environment its proper place among geographic influences by the side of physical environment and biological environment and to welcome its elusive complexities to the domain of thorough-going geography.

Organization of Geography.—Out of the rudimentary instinct of the animal, primitive man and child, to place himself among the multitudinous features of the planet, has grown the formidable array of geographic sciences to which the members of our Association are devoted. The accompanying chart is an attempt to display them as a logical system and to show their relations to one another and to the cognate sciences.[6] Each one of these sciences may be the subject of study and exposition as a unit, and the final result is an analysis of the phenomena involved, from which are derived laws of general application to the whole earth. In each case the work can be done by a specialized geographer, who uses the methods and results of experts in the cognate sciences to discover, display and explain the distribution of the features belonging to his department.

Regional Geography.—Yet all this, vast and varied as it is, may be said to be only a preparation for real geography, supplying the raw material with which the master geographer works. His work

[6] This chart is adapted and elaborated from a chart by Lindley M. Keasbey, *Political Science Quarterly*, Vol. 16, p. 79.

THE ORGANIZATION OF GEOGRAPHY

PHASE	Astronomical Geography	Physical Geography	Biogeography	Anthropography	Economic Geography	Social Geography
SUBJECT MATTER	The Planet Earth	Atmosphere Hydrosphere Lithosphere	Plants Animals	Genus Homo	Natural Resources	Human Societies
PHENOMENA	Planetary	Inorganic	Organic	Generic	Individual	Social
VIEW	Cosmic	Terrestrial	Vital	Taxonomic	Utilitarian	Institutional
PRINCIPLES	Mathematical—Physical	Physical—Chemical	Physiological	Ethnological	Psychological	Sociological
COGNATE SCIENCES	Astronomy Geodesy	Meteorology Hydrology Geology	Botany Zoology	Ethnology Anthropology	Economics Technology	Sociology History Civics Etc.
REGIONAL GEOGRAPHY	Position Boundaries	Climate Drainage Relief Soils	Vegetation Animals	People	Resources Industries	Politics Education Religion Etc.

lies in the field of regional geography, where a synthesis of the contents of a definite and limited environment may be made. The lines of general geographic research, as shown on the chart, and others which might be added, may be likened to so many river systems, each with its tributary branches, which pour their floods, gathered from the whole domain of scientific research, into the trunk stream of regional geography. The regional geographer can not use it all, but it is all at his disposal and no one can tell *a priori* what part will be needed. This view has been expressed with sufficient directness by Prof. Lucien Gallois.

"In the measure that the sciences have developed, especially the natural sciences, . . . in proportion as our horizon has extended by the progress of discoveries permitting fruitful comparisons, the relations of all these facts, one with the other have been better and better perceived, and this *reasoned whole* has ended in constituting a true science, which is geography, as it is uniformly conceived today, wherever there are geographers."[7]

It is in the regional form that geography has finally attained consciousness of its object, its methods, its function,—of itself. "It is the original rôle of geography," says Lespagnol, "to put in contact the facts which other sciences study in isolation." The same idea has been elaborated by Geddes. "All sciences," he says, "are logical artifices by which we focus our attention upon one thing or aspect, with resulting distortion or disproportion, as through a microscope or telescope. They are geolyses or cosmolyses. Geography is more than a science. It is the concrete synthesis of the world in evolution."[8]

Natural Regions.—Regional synthesis has always been practiced. Geographers have distinguished between earth lore and land lore, between geography and chorography, a word which has unfortunately gone out of use while the thing for which it stands has become more prominent. From the beginning there has been description of countries or nations, having only a political or racial unity. Regional geography is now being placed on a scientific basis by the adoption of natural regions as units. The concept of a natural region has been developed in many lands and languages, but among English speaking peoples credit is due above all others to Herbertson. His scheme of Major Natural Regions, presented to the Research Department of the Royal Geographical Society in 1905, bids fair to remain, with minor modifications, a standard for a long time to come. Until his untimely death in 1914, he never ceased to elaborate the scheme of natural regions and to foster an appreciation of their value. He turned the idea over and over in his eminently sane and fertile mind and illumi-

[7] *Annales de Geographie*, Vol. 14, p. 211.

[8] *Contemporary Review*, Vol. 80, p. 707.

nated it with many shrewd and striking expressions. His geographical essay, "The Higher Units," published in *Scientia* in 1913, presents the ripened fruit of his thought. The general inaccessibility of this essay, as well as its pertinence may, I hope, justify quotation from it here.

"This study of geographical distribution of different phenomena was necessary before the geographer could begin the study of the higher problems of his subject. Not that they were unknown. The question of environment has never been left wholly out of account. . . . It was usually the botanist or zoologist or humanist who undertook its examination from the point of view of some particular problems of his own. . . . Why separate organisms from their environment? Plant associations could not exist without a physical environment. The physical elements and the organic elements are but parts of a whole. The higher unit is not physical nor biological, but geographical. . . . A forest is more than an association of trees and other plants. It has its foundation of rock, its floor of soil, its ambient air, the moisture which penetrates it and the sun's rays which play rhythmically on it. The concrete actual geographical entity comprises all of these. Without all it is not complete. It is a continuous space on the outer limits of the solid layers of the earth, with all which it contains, solid and fluid, inorganic and organic. . . .

"It has been suggested that the term macro-organism should be given to this complex entity, the rocks being its skeleton, relatively stable, the soil itself the flesh, the vegetation its epidermal covering with its animal parasites, and the water the circulatory life-blood automatically stirred daily and seasonably by the great solar heart. . . . If the geographical region is a macro-organism then men are its nerve cells. In some of the huge regional creatures this collection of human units is more or less amorphous, a scattered mass of undifferentiated nerve cells, an unimportant part of the whole. In others it is well organized and specialized as an essential part of it, man having set his mark all over its surface. In fact he is a sort of higher nervous system in it. . . . That such regional leviathans exist and that we each are a part of one is the theme of this paper. The personality of such leviathans, like the personality of men, is another question."[9]

As I understand Herbertson, his concept of geography is an interpretation of the relations existing between genetic groups of land forms, dynamic groups of aerial and oceanic forms, physiological groups of plants and animals, and psychological groups of men, existing together in typical natural regions.

[9] *Scientia*, Vol. 14, pp. 203-212, 1913.

THE EARTH AS AN ORGANISM.—The conception of an indefinite number of regional marco-organisms lends a new justification to those enthusiastic and adventurous spirits who have postulated the earth itself as an organism and geography as its anatomy, physiology and psychology. No one has expressed the idea more clearly than Ritter. "There is above all thought of parts, of features, of phenomena, the conception of the earth as a whole, existing in itself and for itself, an organic thing, advancing by growth, and becoming more and more perfect and beautiful. Without trying to impose upon you anything vague and transcendental, I wish you to view the globe as almost a living thing—not a crystal assuming new grace by virtue of an external law, but a world taking on grandeur and worth by virtue of an inward necessity. The individuality of the earth must be the watchword of re-created geography."[10]

Lespagnol treats it with Gallic *verve*. "The earth," he says, "is a sort of organism of which all the parts are in reciprocal dependence. . . . The magnificent accord of the earth and all which germinates and develops on its surface, the harmonious determinism of natural life, give to geography all its beauty and fix its ideal. It endeavors to establish the reciprocal relations of facts of every order, the enchainment of which constitute the life of the earth."[11] It is this "harmonious determinism of natural life" to which Schrader refers in his Herbertson Memorial Lecture of a year ago.

"Man," he says, "must have been a planetary product before becoming a social and moral being—born from dust to rise to thought. Geography, says the old and consecrated definition, is the description of the earth. But that description must not remain only an exterior description and in the body we must try to discern the future apparition of the soul. . . . We must now begin to follow the scientific path which shall perhaps lead the next generations to the great road of scientific harmony between Nature and Man, that still hypothetical harmony, to which Gabriel Séailles, of the Sorbonne, has given the anticipatory name of *Morale Planetaire*."[12]

Henry Wilson, President of the London Society of Arts, gives us a glimpse of transcendental super-geography which he calls geosophy. "There is a geography of thought, a geography of spirit, geography of psychology, of racial influence, a super-physical geography—in fine a geosophy. We want maps of mind, showing the thought and culture currents, idea drifts, spiritual isobars, contours of artistic altitudes."[13]

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[10] Comparative Geography, Gage's Translation, XVII-XXI.

[11] Lespagnol, Geographie Generale, p. v.

[12] Franz Schrader, *Geographical Teacher*, Vol. 10, p. 44.

[13] Henry Wilson, *Geographical Teacher*, Vol. 9, p. 196.

This is not all a castle in the air. Mackinder's "Democratic Ideals and Reality" and Fleure's "Human Geography in West Europe" may be taken as successful flights into lofty regions. Let us leave the seers to their visions on the heights, with the assurance that the dreams of one generation may become the science of the next.

THE TECHNICAL LANGUAGE OF GEOGRAPHY.—Geography is one of the oldest of the sciences, but it has had a long adolescence and is still among the youngest in some aspects of development. It is a white-haired centenarian with the speech of a child of ten. It did not and could not develop beyond the stage attained by the physical and natural sciences. Although the mother of half the sciences in existence, geography is dependent upon her daughters for support. She has been stimulated to reach new stages of growth by repeated transfusions of blood from geology, biology, anthropology and sociology. One evidence of juvenility combined with longevity is that geography has never acquired a technical language. This is due in part to the fact that it has, until recently, been able to express itself by the incomparably graphic method of the map. As long as distributions are the subject, the map is sufficient. When other than spacial relationships are to be expressed, adequate words are needed.

The suggestion of Salisbury that the anomalous state of geography in the schools is due largely to the misfortune of being "in English," has much truth in it. The text-book of geography has hardly a term between its covers which can be called technical. The symbols and formulas of mathematics, chemistry and physics and the boulders of Greek origin which sprinkle the pages of botany, zoology and geology are wanting. Geography is printed in plain English which any ordinarily educated person can understand; therefore it can be taught by any ordinary teacher. Fifteen years ago a list of about three hundred geographical terms was being circulated in England, with a view to reaching an agreement as to their exact meaning and uniform use. Most of them were common words like tarn, mere, glen, combe, down, craig, stack, taken from Scotch and Saxon-English, which are very rich in terms for natural features. Nothing, I think ever came of the attempt. Davis has succeeded in "putting over," at least on American geographers, peneplain, monadnock and cuesta, but only with the help of the geologists. We may hope he will succeed with his latest, "hermatapelago" for a sunken reef sea.

ECOLOGY AND HUMAN GEOGRAPHY.—I, for one, cannot help a feeling of envy when I read books like Warming's (Ecology of Plants and note the wealth of terms which crowd the pages. Here is a science which has sprung into existence and grown without restraint. It has a more "imperially irresponsible control of language" than Shakespeare or G. Stanley Hall, and an unlimited choice of words.

Plants may be heliophilous or photophilous, heliophobous or sciophilous, anemophilous or entomophilous. There are formations of hydrophytes, oxylophytes, psychrophytes, halophytes, lithophytes, and so on through thirteen classes. To the layman all this is darkness, but to the possessor of everyday Greek, each word throws a searchlight on the plant world. Ecology is the youngest born child of geography and has already brought to the family a new interest and vigor, not inferior to the earlier contributions of geology and general biology. The higher geography is fast becoming a universal ecology and ecological methods are surely applicable to men. Why can not organic geography be unified by using ecological language as far as it is pertinent. I will read Warming's statement of the problems of ecological plant geography, and as I read, I ask you to substitute men for plants, humanity for vegetation, institutions for species.

" The general problem how plants or plant communities adjust their forms and behavior to actual conditions.

" Special problems; 1. What species are commonly associated together in similar habitats. 2. The physiognomy of the vegetation and the landscape. 3. Why each species has its own special habit and habitat. 4. Why the species congregate to form definite communities. 5. Why these have a characteristic physiognomy. Problems concerning the economy of plants, the demands they make on their environment, and the means they employ to utilize surrounding conditions and to adapt their internal and external structure and general form for that purpose."[14]

Can the economic and social geographer devise a better scheme than this? In their demands for " a place in the sun," are not men, as well as plants hekistothermic, microthermic, mesothermic, megathermic and magistothermic? The last require high uniform temperatures and may be the prototypes of the Germans. The fact that such plants are extinct may forecast a similar fate for similar men. Why may not the state of the adapted man be called an *epharmony* and human adjustment to a new habitat *ecesis*? One of the outstanding discoveries of ecology is the existence of plant succession, a regular series of associations which follow one another in the same habitat until a climax of stability is reached. Such a succession of plant associations is called a *sere*. Why should not the successive stages of economic life in the human occupation of an area, as in the Middle West, Indian hunting, white pioneer deforestation, developed agriculture and industrial exploitation, constitute and be known as a sere? Much more complex human seres occur in the older countries. As ecological plant geography, which studies the distribution of growth forms determined by environment, overshadows floristic plant

[14] Eugene Warming, Œcology of Plants p. 8.

geography, which studies the distribution of species determined by heredity, so human ecology opens a wider and more fruitful field than ethnology. I venture to put it up to the human geographer, as a serious practical proposition, that he should avail himself of the methods, formulas and as far as practicable, the language of the plant and animal ecologist. Ecology may do for human geography as much as geology has done for physical geography. I see in the not distant future a great work by some master mind, some Ritter or Ratzel, though I hope his name will be Brown, Jones or Robinson, which will place human geography on a basis as scientific as that on which Schimper and Warming have placed plant geography. If that is ever done, it will be by means of a technical language not inferior to theirs.

A Geographic Inscription.—The use of figurative and poetic language in geographic exposition offers an attractive and unworked field of investigation, on which I had thought to comment, but I must not presume upon your patience longer. Something may be reserved for a future meeting of this Association. I will dismiss the subject with a single specimen suggested by the inscription on a stained window of Geddes' Outlook Tower on the Castle Craig of Edinburgh. It might be placed with an appropriate design on the wall of a geographer's laboratory or lecture room, as symbolizing the ultimate geographic concept.

Orbis Terrarum	Orb of the Earth
Microcosmus Naturae	Little World of Nature
Hortus Vitae	Garden of Life
Sedes Hominum	Home of Men
Solum Historiae	Ground of History
Ager Artium	Field of Arts
Eutopia Futuri	Happy Environment of the Future

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THE BOUNDARIES OF THE NEW ENGLAND STATES

SUMNER W. CUSHING*

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INTRODUCTION.—The purpose of this paper is to treat boundaries geographically. The boundaries of the New England states have been selected as the basis for this study of the geography of boundaries, because New England is compact and important, the boundary features are extremely diversified, and the history accessible and illuminating.

All lines used as state boundaries may be grouped in two great classes: topographic and mathematical. The first refers to boundaries whose position is determined by topographic features; the second, to boundaries that bear no necesssary relation to topography and that can be described in exact mathematical terms. The divisions of the two classes are as follows:

WATER BOUNDARIES

SHORE BOUNDARIES. HOW DETERMINED.—The early charters of the New England district made no explicit mention of the character of the limiting line where the colonies bordered the ocean. But such

* This paper was first prepared some years ago. Its partial revision was almost the last work of Professor Cushing before his death early in 1920. At the request of Mrs. Cushing and the Editor, Professor Ellsworth Huntington has kindly assisted in perfecting the manuscript.

phrases as "the Maine Land from Sea to Sea" would seem to imply the coast line as the limit of jurisdiction. The charter given to Gorges, by Charles I in 1639, included "all the Islands and Iletts lyeinge within five leagues of the Mayne." The Virginia charter of 1606, which included present New England, extended this area to "within one hundred miles of the coast." That of the Massachusetts Bay Company of 1691 included "all Islands and Isletts lying within tenn leagues." Other charters avoided such specific reference to the extent of jurisdiction over the sea.

At the present time, by international agreement, the great seas of the earth are neutral to within one marine league of the islands and continents; the remainder of the water area is within the political domain of the country which it borders. It has been suggested that three English miles were chosen as the limit of political jurisdiction because when the limit was fixed,that was the average range of cannon.[1]

A more probable reason seems to be mere convenience, three English miles, or one marine league, being the unit of linear measure on the water. So the sea boundary of New England, as of all countries bordering the ocean, is now "a line following the sinuosities of the seacoast three miles out, but crossing from cape to cape where there is a great land locked water."[2]

This definition of the oceanic boundary was applied to Canada in Article I of the American-British treaty of 1818. But the diplomats who drew up the document failed to specify what was to constitute a land locked water. This was an exceedingly important point, for Article I refers to the rights of United States fishermen to ply their industry in the great fishing ground along the shores of Eastern Canada.

The question arose: "From where must be measured the three marine miles on any of the coast, bays, creeks, or harbors referred to in the said article?" It was the contention of Great Britain that the three marine miles should be measured from an imaginary line from headland to headland irrespective of the size of the bay in question. The United States took the ground that their fishermen had the right to fish in any bay to within three miles of the shore.

This was the most important of seven questions concerning the rights of United States fishermen on the Canadian coast, submitted to the Hague tribunal in June 1910 for arbitration. The tribunal, after sitting from June to September, established a definite law of international jurisprudence, by announcing that: "the three marine miles are to be measured from a straight line drawn across the body of water at the

[1] Ellen Churchill Semple, A Study in Anthropo-Geography, *Bull. Am. Geog. Soc.*, April, 1908, p. 210.

[2] Albert Bushnell Hart, Actual Government, 3d Edition, p. 348.

place where it ceases to have the configuration and characteristics of a bay;" and further that the term "bay" refers to that part of a land locked water landward of the straight line across it "in the part nearest the entrance" and "at the first point where the width does not exceed ten miles." This new principle of international law when applied to the New England coast technically divorces "bay" from "Cape Cod" in the title Cape Cod Bay and converts the bay into a neutral arm of the high seas. Similarly, Nantucket Sound is not within the jurisdiction of Massachusetts, and some of the light ships in the sound are anchored in water that is not within the jurisdiction of the United States. Boston lightship is similarly located. On the other hand Long Island sound, because its entrance is less than ten miles across, lies within the jurisdiction of the United States and is divided between the political domains of New York and Connecticut.

It seems probable that a still more exact definition of the off shore boundary will be called for in the near future when fishing grounds become more valuable, and when the floating population becomes more numerous.

The shore boundary as now defined is difficult to conceive definitely since it depends upon the seacoast for its position, and the word seacoast is ambiguous. It may mean the water line at maximum, mean, or minimum low tide; or at maximum, mean, or minimum high tide. Again, if the boundary is to follow the sinuosities of the seacoast three miles out, it may be conceived as a line similar to the coastline and three miles distant, or a line no part of which is nearer than three miles to the coastline.

Advantages of Shore Boundaries.—In general, the shore boundary has numerous advantages; it is the most obvious of boundary lines, it requires no survey to ascertain its position, no monuments are needed to designate its course. The shore boundary has a further great advantage over all others in that it is a physical and ethnic, as well as a political boundary. It thus is the most harmonious of boundaries. In the history of New England no controversy has ever arisen over the sea shore as a boundary.

It may be said that the shore boundary has a disadvantage because the coast line may change rapidly, as happens along the coast of sandy islands bordering the outer margin of a coastal plain. Near Atlantic City, New Jersey, one estate may lose several acres in a few years, and another gain as much in the same time. Nevertheless, the changes do not cause a transfer of jurisdiction from one government to another, and so do not lead to disputes, as do changes in the course of rivers which serve as boundary lines.

In times of war, the sea boundary is one of the easiest to defend.

The harbors are like mountain passes; being the only ways of easy access, they make it possible for all the defensive forces to be concentrated at a few points. Macauley emphasizes this advantage in considering countries which are largely bounded by the sea. "Some states have been enabled by their geographical position to defend themselves with advantage against immense forces. The sea has repeatedly protected England against the fury of the whole Continent. The Venetian Government, driven from its possessions on the land, could still bid defiance to the Confederacy of Cambray from the arsenal amid the lagoons." In the case of a very irregular coastline, like that of Maine, however, where the harbors are over numerous the ease of defense is lessened.

In times of peace, the modern development of marine transportation causes a country with an ocean boundary to be close neighbors with half the world, and is one of the best means of promoting commercial prosperity. The extent and character of her coastal boundary has done as much as anything else to build up New England's manufactures and commerce. In short, in spite of the difficulties in the interpretation of the term, shore boundaries possess great advantages and are quite free from the disadvantages which we shall soon see to be common among some other boundary lines.

River Boundaries. Their Types.—The position of a river boundary may be determined by any part of a river, such as the middle a bank, the deepest channel, etc. Moreover, in this paper, a subclass under this head includes boundaries that are determined by reference to a river, for example, "parallel to and three miles north of" a stream. In New England the river boundary takes first place both in length and the number of references made to it in the charters, grants, acts, and agreements.

No other boundary feature offers so many parts that may be taken to determine the position of boundary lines. New England seems to exhaust the list of possible references, as appears in the following descriptions.

River. No Part Specified.—In some cases where the river is inconspicuous in width no part is specified as the boundary, as is illustrated in a part of the northeastern boundary of Maine (3).[3] Here the line goes "Southerly, by the said branch, (the southwest branch of the St. John's) to the source thereof." (Treaty of Great Britain 1842). Another example of this is found in the most southern portion of the New York-Connecticut line, where the boundary begins "in the mouth of a brook or a river called Byram's River, where it falls into

[3] Numbers in parenthesis refer to boundary lines shown on map, page 21.

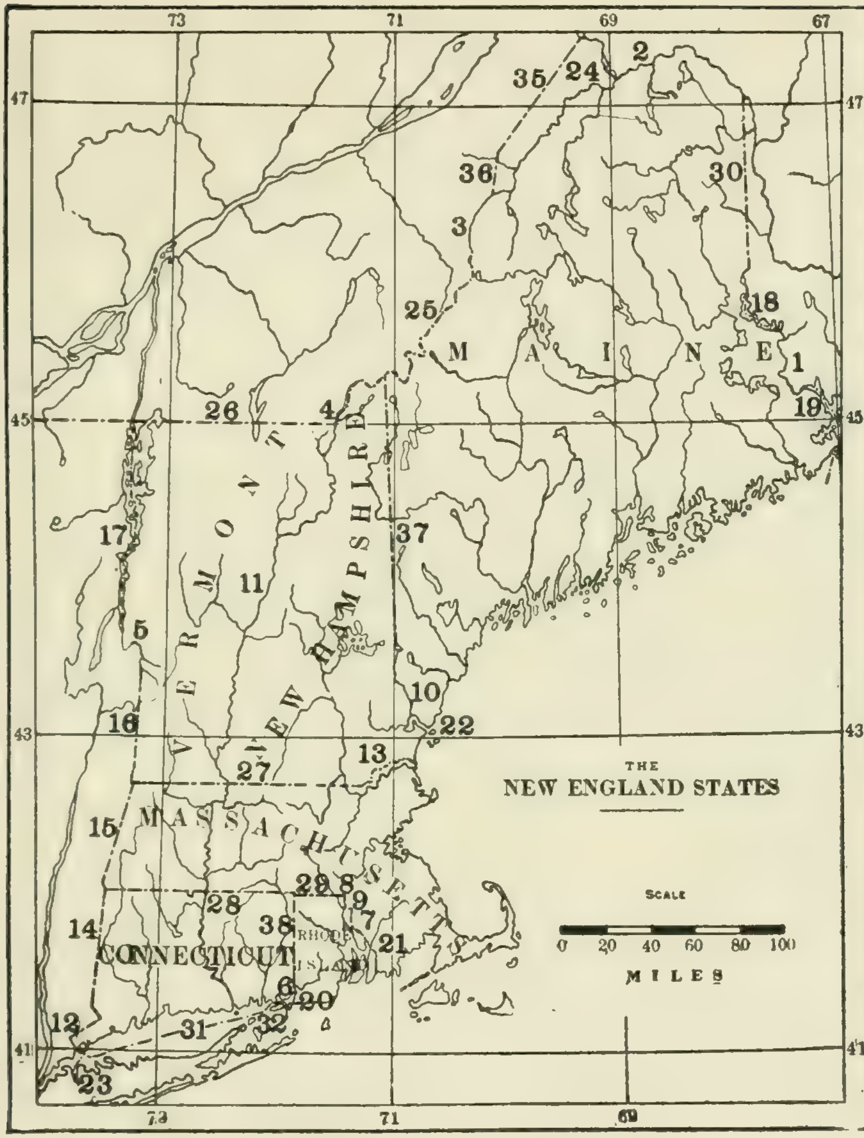

FIG. 1. Location map for points cited in text.

Long Island Sound, and running thence up along said river . . . " (12). (Revised Statutes of New York 1881).

MIDDLE OF VARIOUS PARTS.—The most common part of a river designated for a boundary line is the middle of its course or of the channel. This is the part of the river St. Croix used for a portion of the eastern boundary of the State of Maine. The treaty of 1782 with

Great Britain defined it as " a line to be drawn *along the middle of the river* St. Croix, from its mouth in the Bay of Fundy to its source " (1).

A part of the northern boundary of Maine is a line which runs " *up the middle of the main channel* of the said river St. John, to the mouth of the river St. Francis; thence *up the middle of the channel* of the said river St. Francis, . . . " (2). (Art. I. Treaty of Great Britain 1842). Nearly half of the north boundary of New Hampshire is a similar line (4), it being a line that runs " *down the middle of said stream* . . ." (Hall's stream). (Treaty with Great Britain 1842). " *The middle of the deepest channel* " is the phrase that describes a small portion of the New York-Vermont line in reference to the Poultney river (5). (Act of Congress, April 7, 1880).

Again, the southern portion of the Rhode Island-Connecticut boundary furnishes an illustration of this type, under a wording of new variety. In a charter given to Rhode Island and Providence Plantations by Charles II in 1663, the country was described as " bounded on the west or westerly, *to the middle or channel of a river there* commonly called and known by the name of Pawcatuck . . . , and soe along the sayd river, as *the greater or middle streame* thereof reacheth or lyes upp into the north countrye . . . ." (6).

The Massachusetts-Rhode Island commissioners in 1860 attempted a more specific designation for the same type of boundary when they described a small part of the line between their states (7), as running " *through the center or middle of said Runnin's River as the same is at low water.*"

The southern fourth of the Maine-New Hampshire line, shows the boundary " *passing up the middle of the river* of Newichwannock, part of which is now called the Salmon Falls, and through the middle of the same to the farthest head thereof. . . " (10). (Commissioners' Report of 1829).

A line that follows the midstream, channel, etc., seems to be the most impartial one, if any part of a river is to serve as the line. It was probably on this account that this phrasing was so much used in New England. The great variety of expressions used in referring to practically the same part evidently resulted from a lack of standardized boundary definitions.

River Bank.—When King Charles II of England in 1664 gave to his brother, the Duke of York, " all the land from the west side of Connecticut River to ye east side of Delaware Bay " he established a precedent that eventually determined George III, a hundred years later, to declare " *the Western banks* of the river Connecticut " to be the western boundary of New Hampshire (11). Since the Con-

necticut river is entirely within the jurisdiction of New Hampshire, that state collects revenue from all factories using the river for power even if they are located on the Vermont shore. It also has the responsibility of building and keeping in repair all the bridges to Vermont. (Letter from the N. H. Secretary of State 1910).

Highest Water Mark.—A peculiar local type of river boundary is found along the eastern border of Rhode Island, where the highest water mark is designated as a boundary. The line follows "*the highest water mark* on the easterly side of Farmer's or Seven Mile River" (8), and "*the highest water mark* on the southerly and easterly side of said Ten Mile River" (9). (Decree of U. S. Supreme Court 1861).

River Boundaries. Determined by Reference.—This type of line might well be considered under another head since it runs over the land at some distance from the river to which it is related. But as its direction, position, and contour are supposedly determined by a river, it seems best to discuss it here.

The most striking example of this class of river boundaries is the eastern two-fifths of the Massachusetts-New Hampshire line (13). This was described in a declaration of the King in 1740 "as a similar curve line pursuing the course of the Merrimac River, at three miles distance on the north side thereof, beginning at the Atlantic Ocean and ending at a point due north of Pawtucket Falls."[4]

The only other example in New England of a boundary determined by reference to a river is between New York on the one hand and Connecticut, Massachusetts and a portion of Vermont on the other. The Connecticut portion of this line (14) was first described as "parallel to the Hudson and twenty miles distant from it, until the bounds of Massachusetts were reached."[5] Later it was observed that if its course followed the constant, though slight bends in the river "it would be of such an irregular and 'zig-zag' character, as to make it quite unsuited for a permanent boundary between two states."[6] So it was agreed that the line should be a straight line, with a general direction the same as that of the Hudson River, and twenty miles distant from it.

As actually run the line deserves to be classed with mathematical boundaries; and in its relation to the topography of the district it is

[4] Henry Gannett, Boundaries of the United States (3d Edition), *Bull.* 226, *U. S. Geol. Surv.*, p. 48.

[5] S. E. Baldwin, Boundary Line Between Connecticut and New York, *New Haven Historical Society Papers*, Vol. III, p. 278.

[6] *Ibid.*

almost a crest line, and a divide. At the time it was run, it coincided with the *ethnic* boundary between the Dutch and English colonies. So it has the peculiar distinction of coming under six distinct classes of boundary lines. The same characteristics hold throughout most of the northern extension of the New England-New York boundary to Poultney River.

The early coincidence of the ethnic, physical and political boundaries in this region was not accidental. The Indians sold grants of land along the Hudson, above the gorge, to the Dutch and described the eastern boundary as a line parallel to the Hudson and half a day's walk distant. This is practically the crest of the highlands. The Dutch settled their grant and came under the jurisdiction of New Amsterdam which is now New York. So it would seem that topography was the controlling factor in fixing the position of the line.

In Massachusetts the precedent established by Connecticut and New York was followed, for the line is here straight, with termini twenty miles from the Hudson River, so that it follows the general course of the river (15). A nearly similar relation holds in the Vermont section of the line (16).

Advantages of River Boundaries.—The most obvious advantage of a river boundary is that it can be easily described in a treaty and indicated on a map. Moreover, its position is so unmistakable, that no survey is needed to identify it. Again, except where interrupted by falls and rapids so that it can be used for power, a river seldom leads to industrial controversies between the sections which it bounds. Also in times of war the river boundary has to a certain degree the same advantages as a coast with its harbors and a mountain range with its passes. The fording places and bridges like the harbors and passes are but places for the concentration of forces, while the other parts may serve as lines of protection. The New England states have never had occasion to test this use of the river boundary.

All the disputes over river boundaries in New England have resulted from the inadequate wording of treaties, as in the cases where the St. Croix river is mentioned without stating which of the several rivers of that name is meant, or from hostility to accepting a certain river as a boundary because it did not include the right area, which happened when New Hampshire refused to accept the Connecticut as her western boundary. There has been no controversy over the position of the line when once a river was accepted.

Disadvantages of River Boundaries.—Of the disadvantages of the river boundary probably the greatest results from the inconstancy of rivers. The part specified in a treaty is liable to change, be it

the middle of the river, the main channel, the deepest channel, one of the banks, or highest or lowest water mark, and with a change may come controversies and inconveniences. This is especially true of rivers meandering in broad flood plains, for such are likely to change their course and transfer much land and possibly people from one jurisdiction to another. The lower Rio Grande has often played such a part and by transferring people from the United States to Mexico or the reverse has well demonstrated the inconveniences of river boundaries. Since New England has been recently glaciated, it has few rivers of this type, and none of these now serve as boundaries.

Rivers with falls, which are valuable commercially, are often sources of disputes if they serve as boundary lines, especially between nations. The Niagara is most famous. In 1910 the water power of the Niagara and other rivers between the Great Lakes led to a treaty between the United States and Great Britain which establishes an international commission to investigate any question arising in respect to the boundary.

Lord Curzon[7] points out that rivers as the creation of nature, in contradistinction to the creation of man, are natural boundaries; but in relation to the natural habits of man, rivers are not the natural divisions, because people of the same race are apt to reside on both banks. This relation of rivers to people, in the early history of New England, nearly established a new state under the title of "New Connecticut," in the valley of the Connecticut river, north of the Massachusetts line. Settlers on one side of the river had closer social bonds with those on the other side, than they had with the colonists over the divide at their backs, and so they desired close political union with them. Outside influence prevented the consummation of this inclination.

A similar relation between rivers and people was responsible for moving the northern limit of New England from the St. Lawrence river, as it was previous to the cession of Canada from France to Great Britain in 1763, southward to a divide.

3. Lake Boundaries.—The northern two-thirds of the New York-Vermont boundary is the most conspicuous example of a lake boundary in New England (17).

Here, in Lake Champlain the line follows the deepest channel between certain islands. The longest and probably the most important lake boundary in the world, that of the United States and Canada in the Great Lakes, with the exception of part of Lake Superior, follows the middle course of the lakes. This seems to be the just position of such a boundary. Conditions in Lake Champlain rendered such a position inadvisable for numerous islands would have been thereby divided between the adjacent states.

[7] Lord Curzon of Kedelston, Frontiers (3d Edition), p. 20.

The Commissioners' report of 1814 describes the line as running "*through the middle of the deepest channel* of East Bay (a small southern arm of Lake Champlain) and the waters thereof to where the same communicate with Lake Champlain; then *through the deepest channel of Lake Champlain* to the eastward of the islands called the Four Brothers, and then westward of the islands called the Grand Isle and Long Isle, or the Two Heroes, and to the westward of the Isle La Motte to the line in the forty-fifth degree of north latitude, . . ."

Another example of lake boundaries in New England is the Schoodic Lakes along the east boundary of Maine (18). No specific mention is made of these in any treaty relating to the northeast boundary. Although they are in numerous places over four miles wide, they are evidently considered a part of the St. Croix river, and hence the boundary follows their middle course.

For a few miles the eastern boundary of Rhode Island is a lake boundary (21). In the Supreme Court decree of 1861, this was described as running southerly along "*The highest watermark on westerly side of South Watuppa Pond,* and of Sawdy Pond, and of the streams connecting said ponds. . . ." The reason for the use of the highest watermark for the line, seems to be that the ponds here mentioned were reservoirs for Massachusetts towns, at the time the boundary was settled.

The more usual variety of lake boundary is illustrated in northern Maine, where the boundary for about twelve miles is through lakes (24). Article I of the Treaty with Great Britain of 1842, describes it thus: "thence up the middle of the channel of the said river St. Francis, and of the lakes through which it flows. . . ."

Sound Boundary.—The southern boundary of Connecticut is a line through Long Island Sound, (23-31-32). For years Connecticut acknowledged that New York owned "all the islands specifically named in her boundary statute" . . . but she denied "that the general dividing line between the States is farther north than the middle line of the Sound."[8] Thus it seemed at one time that the middle line of the Sound would become the boundary, but in 1880 commissioners made the Sound line a series of mathematical lines and their report was ratified. These lines practically follow the middle of the Sound but since no part of the Sound is referred to as a controlling factor in determining the character, position, or direction of this line, they are left for consideration under mathematical boundaries.

[8] S. E. Baldwin, Boundary Line Between Connecticut and New York, *New Haven Historical Society Papers,* Vol. III, p. 287.

Bay Boundaries.—The southern portion of the international boundary between Maine and New Brunswick is a bay boundary (19). In the treaty with Great Britain of 1872, Article II refers to this boundary in these words " a line to be drawn along the middle of the River St. Croix, from its mouth in the bay of Fundy, to its source," and further on, " comprehending all islands . . . lying between lines to be drawn due east from the points, where the aforesaid boundaries . . . shall respectively touch the Bay of Fundy, and the Atlantic Ocean; excepting such islands as now are, or heretofore have been, within the limits of the said Province of Nova Scotia."[9]

The first reference gives merely the starting point, the first part of the second would make the boundary a parallel, and the last part nullifies the first by making it a tortuous line in the bay, winding seaward among the islands. A Board of Commissioners awarded three of these islands to the United States and all the rest to Great Britain. As the line is today then, it has no more specific position as far as its description goes, than a line of separation among islands.

Actually the line is carefully marked by means of white buoys. The need of nice designation is prominently felt here because of the excellent lobster grounds throughout the bay, and the diversity of the laws of Maine and New Brunswick that control the taking of lobsters. Maine protects the young throughout the year by prescribing a minimum length, and New Brunswick aims to conserve the supply by establishing a closed season of seven months, and a minimum length, less than that of Maine, during the open season. This condition offers an opportunity to the fishermen on both sides for increasing their profits, by stealthily ignoring the position of the line.

The southern part of the Rhode Island-Connecticut boundary is a bay boundary (20). It follows the midline of Little Narragansett Bay for several miles. The bay is an open lagoon in a glacial outwash plain into which a river empties. It seems to have been taken to be a part of the river, for the charter of Charles II of 1663, describes Rhode Island as extending to the west, " to the middle or channel of a river there. . . . "[10] with no specific mention of the bay boundary.

The Southern portion of the Maine-New Hampshire line is a bay boundary (22). His Majesty's commissioners reported, in 1735, " That the dividing line shall pass up through the mouth of Piscataqua Harbor, and up the middle of the river," and, " that the dividing line shall part the Isle of Sholes, and run through the middle of the harbor, between the islands, to the sea on the southerly side. . . . "[11]

[9] A. Gallatin, Northeastern Boundary, 1840, p. 9.

[10] Henry Gannett, Boundaries of the United States (3d Edition), *Bull. 226, U. S. Geol. Surv.*, p. 71.

[11] *Ibid*, p. 42.

Bay boundaries are sometimes marked by beacons on land or by buoys in the water. If the latter are used they are liable to be confused with channel markers. So the exact position of the line is difficult to determine.

Bays are usually used for harbors, and most harbors are places of concentrated activity where strict and prompt jurisdiction is required. If a line in a bay is used for a boundary, it tends to prohibit this desirable jurisdiction for vessels may anchor near the line and so be in a questionable position in relation to jurisdiction. The application of quarantine or health laws, or those pertaining to navigation, passengers, fishing, and the like, may be thus hindered. This disadvantage in the bay boundary has been overcome in the Delaware-New Jersey line by permitting each state " to enjoy and exercise a concurrent jurisdiction within and upon " the water of Delaware river and bay.

In the first cession of land from Mexico the United States was careful to obviate this disadvantage by having the western part of the line drawn " to a point on the coast of the Pacific ocean distant one marine league due south of . . . the port of San Diego,"[12]

An advantage of a bay boundary if it be adapted to serve as a harbor, is that it gives both the adjacent states or countries an aid to industrial development, whereas another line in such a region might turn the advantage to only one, especially if harbors were few in the vicinity.

HIGHLAND BOUNDARIES.

Divide Boundaries.—In New England, for over eighty years, a boundary determined by a divide was the cause of disputes. Historically, this line was first described by a proclamation issued by Great Britain, in 1763, following the Peace of Paris of that year. The line was to cross the St. Lawrence and Lake Champlain in the 45th degree of north latitude, " and thence to proceed along the highlands which divide the rivers that empty themselves into the St. Lawrence from those which fall into the sea."[13]

This precedent led Great Britain, in the treaty of 1782, in describing the limits of the United States, to declare this part of the boundary to be " From the northwest angle of Nova Scotia . . . along the highlands which divide those rivers that empty themselves into the river St. Lawrence from those which fall into the Atlantic Ocean, to the northwestern-most head of Connecticut River. . . . "

It will be observed from the map (Fig. 1) that there is a main

[12] *Ibid*, p. 24.

[13] Daniel Webster, Works, Vol. II, p. 147.

divide and a subdivide in this section of the country. One truly divides all the rivers flowing into the Atlantic from those emptying into the St. Lawrence; the other separates the basins of the St. Croix, Penobscot, Kennebec, etc., from those of St. John, Chaudiere, St. Francis, Yamaska, etc. But the St. John is an Atlantic river and so ought not to be grouped with the St. Lawrence rivers. However, Great Britain reasoned that as in the treaty the St. Lawrence bay was not considered a part of the Atlantic ocean, so the Bay of Fundy, into which the St. John empties, should not be so considered. Hence the St. John is not an Atlantic flowing river. So the highlands to the south were those referred to according to the contention of Great Britain. She was so persistent in this view, apparently for strategic reasons, that compromise finally resulted, concerning which, Webster, who represented the United States, declared the underlying principle to be "that the arrangement shall be for the mutual convenience and advantage of both parties, if the terms can be made fair, and equal, and honorable to both."[14]

As a result the divide boundary was cut down to one fourth the length it would have had, had the "American line" been adopted. As it is today, the boundary extends from the source of the southwest branch of the St. John's "in the highlands at the Metjarmette portage; thence down along the said highlands which divide the waters which empty themselves into the river St. Lawrence, from those which fall into the Atlantic Ocean, to the head of Hall's stream"[15] (25).

The geographic lesson taught by such an outcome seems to be that in a little known country even a divide boundary designated with careful specifications, can be brought into dispute, if the incentive is great enough.

As has been stated above, the line which forms the western boundary of Connecticut, Massachusetts and a portion of Vermont, (14-15-16), practically follows a divide which is nearly at the crest of the Taconic Mountains. Along the southern course, it is the divide between the Hudson basin and that of the Housatonic; and in the northern part, it is a subdivide between the Hudson and its tributaries, especially the Hoosic. But since this boundary was not defined as a divide boundary, it will not be considered here as such.

Crest Boundary.—A crest boundary may be defined as one that follows the highest parts or summits of a range of hills or mountains. It does not necessarily coincide with the divide, for any considerable distance, and may not even approximate it. Land forms are so variant

[14] *Ibid*, p. 151.

[15] Henry Gannett, Boundaries of the United States (3d Edition), *Bull.* 226, *U. S. Geol. Surv.*, p. 17.

in degree of resistance that some rivers, by headward erosion, or otherwise, may have carved their valleys far beyond the general crest line, while others are just approaching it. So the crest line is often very discontinuous. Such is the relation between the divide and crest line in the Andes, where is located the disputed Argentina-Chile boundary; also, in the northward extension of the Rockies, where the Alaska-Canada line was first described as following the summit of the mountains situated parallel with the coast.

As far as specific reference to a crest line goes, New England furnishes no example in her boundaries. But in following a line parallel with and twenty miles east of the Hudson, sections of the eastern New York boundary approximate closely the crest line of the Taconic Mountains, as has already been noticed.

Crest lines, like divides, form lines of separation far from the scenes of people's usual activities, and thus are well adapted to serve as boundaries. But because they are seldom continuous and at best difficult to ascertain, they are less desirable than are divides. Lord Curzon[16] in referring to the Alaska-Canada line, questions "the practicability or meaning of a line that scaled inaccessible peaks and was lost amid ice and eternal snow."

MATHEMATICAL BOUNDARIES.

Parallels.—The shape of the earth is such that lines can be precisely located on its surface in relation to its daily motion. One set of lines so determined are east-west lines or parallels. They are more extensively used as boundary lines in the United States than are any other mathematical lines.

In fact, with the exception of Maine, New Jersey, and Ohio, there is no state in the Union that does not include at least part of one parallel in its boundary. Even in Maine part of the boundary was originally described as a "due east line" but was nullified later; and Ohio, in her constitution, defined the northern boundary as an "east and west line" but that was also made void. One cause for the extensive use of parallels in United States seems to be the comparative ease with which they can be described by diplomats in relation to sections sparsely inhabited, and little known. Another cause that probably had some influence, is the north and south direction of the coast line and the habit of making one set of boundary lines at right angles to the coast line. Still another cause is the early movement of settlement from east to west.

In New England the international representative of this type of boundary is in Vermont (26). In the Treaty of 1842 with Great

[16] Lord Curzon of Kedelston, Frontiers (2d Edition), p. 36.

Britain, this was referred to as "the old boundary surveyed and marked by Valentine and Collins, previously to the year 1774, as the 45th degree of north latitude. . . . " This boundary was first described when England acquired Canada from France in 1763 by the Peace of Paris. It was then that the claim of Massachusetts to the north bank of the St. Lawrence river was disallowed by England and Massachusetts was limited by a line "that was to cross the St. Lawrence and Lake Champlain in the 45th degree of north latitude, and thence to proceed along the highlands. . . . "[17]

In making this change Great Britain was apparently prompted by a desire to bring her newly acquired sections of ethnic homogeneity, (Quebec, New Brunswick and Nova Scotia) into closer physical or geographic union. When the desire was felt, the maps of the region were inadequate to suggest to British diplomats any physical features that might serve the purpose of a boundary, and the region had been little explored. Hence for convenience and exactness the parallel seems to have been adopted.

The greater parts of the northern and southern boundaries of Massachusetts (27 and 28) are described in the original grants, in terms that would seem to mean parallels, and attempts were made to locate them as such, but inadequate geographic knowledge prevented this. In a decision promulgated by the Lords of Trade in March, 1740, the western part of the northern boundary of Massachusetts was described as beginning at a point "three miles due north of Pawtucket Falls, and thence due west to His Majesty's other governments."[18] Thus three fourths of the northern boundary of Massachusetts was defined as the parallel passing through a point three miles due north of Pawtucket Falls on the Merrimac. Richard Hazen attempted to mark this line in 1741, under instruction from Governor Belcher, and allowed for a westerly variation of the needle of 10 degrees. This variation was later found to be too large.

Another error was made in the line, for a constant variation of 10 degrees was used, whereas it should have been constantly decreased from east to west, the total decrease being about one degree. Hence the line curves to the north, favoring Massachusetts. Nevertheless, the line as run was accepted and is still the boundary.

The other Massachusetts boundary that was first interpreted to be a parallel (28-29) was defined in a grant from the council of Plymouth of 1628 in these terms: "all . . . landes . . . lyeing within the space of Three Englishe Myles on the South Parte of the said River called Charles River, or of any or every Parte thereof . . . lyeing within the Lymitts aforesaid, North and South, in Latitude

[17] Daniel Webster, Works, Vol. II, p. 147.

[18] W. Harriman, History of Warner, N. H., p. 561.

and Breadth, and in Length and Longitude . . . from the Atlantic . . . ocean . . . to the South Sea."[19]

Commissioners from Massachusetts and Rhode Island in 1710 discarded the due west line, for some reason not apparent, and adopted one that was to start from a point " 3 English miles distant southward from the southernmost part of the river called Charles River," and run, " so it may (at Connecticut River) be two and one half miles to the southward of a due west line." This brought about a series of controversies over this section of the line (29), that lasted for nearly two hundred years and in which were involved two appeals to the Supreme Court of the United States. Gannett pronounces this prolonged dispute " in some respects the most remarkable boundary case with which this country has had to do."[20]

The reason for this seems geographic. The country over which the line was to run was comparatively level and relatively inviting for settlement, and although distant from the coast line, was much frequented by colonists passing between the Massachusetts Bay settlements and those of Long Island Sound and Narragansett Bay. Thus it was early known and settled, long before an attempt was made to fix the boundary line formally. As early as 1642 a stake was set up on the plain at Wrentham to mark the commencement of the line but the westward extension was not designated. Each colony granted to settlers sections which were presumed to be within its jurisdiction. But since the definition referred the line to no topographic feature, except the point of departure, it could not be ascertained exactly except by skilled geodesists. Thus is illustrated one of the disadvantages of the mathematical line as a boundary. Nevertheless a line of jurisdiction was early established, but this only approximated the defined line of the grant. This gave the colonies, and later the states, many grounds for dispute, and so followed a long controversy. The jurisdictional boundary, a very irregular line, was finally adopted in 1881 and is still extant. It is treated under parallels because its progenitor was a parallel, and a parallel determined its general direction, position, and extent.

The other portion of the parallel which is a part of the southern boundary of Massachusetts, is that separating it from Connecticut (28). This underwent a similar history, and reached a termination similar to the Rhode Island section. As it is today, it is made up of sections of parallels, other mathematical lines (town boundaries), and short topographic lines. It however approximates the parallel originally

[19] Henry Gannett, Boundaries of the United States (3d Edition), *Bull.* 226, *U. S. Geol. Surv.*, p. 54.

[20] *Ibid*, p 55.

described as that of a point three miles south of the southernmost part of the Charles River.

The method of defining a boundary by giving its latitude in degrees as was done with the parallel of 45° in northern Vermont, is very common in the West. Another means, however, has been employed in separating North and South Dakota. The dividing line agreed upon when they were admitted as states was the "seventh standard parallel" from the base of the fifth principal meridian. The "standard parallels" are those which have been carefully laid out by government geodesists in certain parts of the country, as standards for local surveys of boundaries of smaller divisions. "This line is about four miles south of the parallel 40 degrees from the Equator, and was chosen in preference to the geographic parallel because it was the boundary line between farms, sections, townships, and to a considerable extent, counties."[21]

A peculiar method of referring to parallels is found in the Treaty with Great Britain in 1782 in defining the limits of the United States. The line was defined to the Mississippi River, "thence by a line to be drawn along the middle of the said river Mississippi until it shall intersect *the northernmost part of the thirty-first degree of* north latitude."[22] The same method was employed in the Revised Statute of New York of 1881, relative to the southern boundary of that state. The act reads: "then south along said meridian line to a monument *in the beginning of the forty-third degree of north latitude* . . . then east along the line . . . in the same parallel of latitude."[23] The parallel meant here is the forty-second. It was so run and marked.

In both cases the idea of a parallel of latitude seems to be a band about the earth parallel to the equator and one degree wide, with the "begining" nearest the equator.

The advantages and disadvantages of parallels as boundaries are nearly identical with those of other mathematical lines, so they will be numerated later in relation to the larger class.

Meridians.—In the United States among mathematical boundaries, meridians are second only to parallels in extensiveness of use. Meridians as boundaries are illustrated in New England by the northern half of the eastern boundary of Maine (30), and the greater part of the Rhode Island-Connecticut boundary (38).

The Maine line is first referred to in the treaty with Great Britain of 1782 in a description of the northwest angle of Nova Scotia, as

[21] W. E. Johnson Mathematical Geography, p. 234.

[22] Henry Gannett, Boundaries of the United States (3d Edition), *Bull.* 226, *U. S. Geol. Surv.*, p. 9.

[23] *Ibid*, p. 82.

"that angle which is formed by a line drawn *due north* from the source of St. Croix River to the highland." Farther on in defining the eastern boundary of the United States it is said that a line is "to be drawn along the middle of the river St. Croix from its mouth . . . to its source, and from its source directly north to the aforesaid highlands."

It is significant that although prolonged disputes arose concerning the position of the source of the St. Croix, and the highlands that were referred to, there was none over the meridian part of the boundary at any time.

The Rhode Island line is the meridian of the mouth of a tributary. In the charter to Rhode Island, granted by Charles II in 1663, the country was bounded on the west by Pawcatuck river to the head, "and from thence, by a straight lyne drawn due north until it meets with the south lyne of the Massachusetts Colony."[24] Difficulties in locating the main part of the Pawcatuck river, led to a compromise that determined the mouth of Ashawoga river, a tributary, as the starting point of the meridian. In surveying the line the meridian was marked part of the way, but elsewhere, a series of short straight lines forming the jurisdictional boundaries of previous township grants was followed, for those had tried to follow the described line.

In naming meridians as boundaries the more usual custom in the United States is to give their distances from a prime meridian, either that of Greenwich or Washington, instead of the meridians of topographic features as in Maine and Rhode Island. Previous to 1861, Greenwich was the standard for meridians used as boundaries in the United States. At that time, however, in the act that enabled Kansas to become a state, the western boundary was described as "the 25th meridian of longitude west of Washington." Since then Washington has been the standard in such cases. The boundaries of Nebraska, North and South Dakota, Wyoming, Colorado, New Mexico and Utah are examples of this. It seems as if patriotic reasons were responsible for this change.

Thus the eastern boundary of New Mexico is the 103rd meridian west of Greenwich and the western boundary of the same state, the 32nd meridian west of that of Washington. When defined in relation to a standard meridian the task of locating the initial point is more difficult and the possibility of error greater than when the meridian of a topographic feature is the boundary.

In locating a point of the 100th Meridian as the eastern boundary of northern Texas, after using the best instruments obtainable in

[24] *Ibid*, p. 71.

numerous trials, H. S. Pritchett reported a probable error of plus or minus seventy-three feet, and declared that this could not be " appreciably reduced without a redetermination of transatlantic longitudes."[25]

" STRAIGHT LINE " BOUNDARIES.—The " straight line " as used in a boundary definition means the line of intersection between the earth's surface and a plain which contains the termini of the line and the center of the earth, and which unlike a meridian or parallel, does not depend upon the movement of the earth for its direction. Although called " straight " this line is usually very irregular, due to the irregularities of the surface over which it runs. And if the surface were an ideal plain, the line would not be straight because it would be on the surface of a nearly spherical body, the earth. It would really be the arc of a great circle.

After all, the limit of jurisdiction is a plane. The aerial extension may not be commonly conceived until aeroplanes and balloons become much more numerous, but the subterranean extension is of great importance in mining regions. So a boundary is really a plane. It was so acknowledged in a description of a boundary monument to be used on the U. S.-Mexico line as given in a report of the Commissioners. It reads; " These rings will be placed, one at the top of shaft, the others twelve inches below, and will be carefully located *in the plane of the boundary*."

Under this conception the straight line boundary becomes a part of a plane which contains the given termini and the center of the earth. It is the intersection of this plane and the earth's surface nevertheless that monuments mark; so that is the important thing, as far as the present use of the boundary outside of mining regions is concerned.

An example of the " straight line " boundary in New England is the northern portion of the Maine-Quebec line (35), which is a portion of the compromise line between Canada and the United States. In the treaty with Great Britain of 1842, it is described as running from the outlet of Lake Pokenagamook; " thence southwesterly, in a straight line, to a point on the northwest branch of the river St. John, which point shall be ten miles distant from the main branch of the St. John, in a straight line, and in the nearest direction." In this case drainage features are used to determine the position of the termini, with another straight line as an auxiliary.

The next section of the compromise line to the south is also a straight line (36). From the southern terminus of the line just described, it runs, " in a straight line, in a course about south, eight

[25] M. Baker, The Northwest Boundary of Texas, *Bull.* 194, *U. S. Geol. Surv.*, p. 35.

degrees west, to the point where the parallel of latitude 46 degrees 25 minutes north intersects the southwest branch of the St. John's." Such a reference to a point could be made only in a region that had been carefully mapped and such a point could not be actually located without the aid of skillful geodesists. The line has numerous monuments to show its course.

The longest straight line boundary in New England is the central part of the Connecticut-Long Island line (31). The ratified report of the commissioners in 1880 gave this part as running from the end of a true southeast course three and a quarter statute miles from Byram Point, " thence in a straight line (the arc of a great circle) northeasterly to a point four statute miles due south of New London Light House; . . . ."[26] This line is eighty-two statute miles long. With a few short segments of loxodromic curves at either end it determines the respective jurisdictions of New York and Connecticut over the waters and islands of Long Island Sound.

The straight line boundary is illustrated outside New England by portions of the U. S.-Mexico line. California is separated from Lower California by " a straight line drawn from the middle of Rio Gila, where it unites with the Colorado, to a point on the coast of the Pacific Ocean distant one marine league due south of the southwesternmost point of the port of San Diego."[27]

Such a line was used in the Gadsden Purchase of 1853, with short stretches of parallels and meridians. It follows roughly the southern divide the Gila River and so fixes a large part of the United States-Mexico boundary. The reason why the mathematical approximate of this divide should have been used instead of the topographic feature is not clear. The topography is everywhere pronounced making the divide conspicuous. Thus it would have required only a hasty reconnoissance to locate the line and only a few monuments to mark it. As it was, an extended and costly survey had to be made and many monuments erected, some with difficulty and hazard on precipitous slopes.

A rectangular relation is found between the straight line and the divide in the northern part of the Wisconsin-Michigan boundary. A similar relation holds between a straight line and the divide between the Hudson Bay and Gulf drainage in a part of the Minnesota-South Dakota line.

The New York-New Jersey boundary is " a direct or straight line." Before the District of Columbia ceded a portion of its area to Virginia, it was practically a square, bounded by four ten-mile " direct "

[26] Henry Gannett, The Boundaries of the United States (3d Edition), *Bull.* 226, *U. S. Geol. Surv.*, p. 76.

[27] *Ibid.*, p. 24.

lines. The longest "straight line" boundary on the earth is that which constitutes the greater part of the eastern limit of California.

Loxodrome Boundaries.—The loxodrome boundary is a curve that cuts all meridians at the same angle and is oblique to parallels, or it may be defined as a line of constant bearing. It will be observed that this line is unlike the "straight line" in that it cannot be contained in a plane.

In early times, when surveyors had meagre and uncertain knowledge concerning the magnetic variation of the compass, they often allowed for too much or too little variation in fixing boundaries, determined by parallels of latitude. The resulting line was a loxodrome, providing correction was made for the differences of variation in different places. Thus, if the latter provision had been made in running the parallel of northern Massachusetts, since the primary variation was too great, the line would have been a loxodrome. As it is the line is very nearly one.

The mathematical portion of the Maine-New Hampshire boundary (37) is a loxodrome as expressed in the report of a board of commissioners in 1737. From the "furthest head" of the Newhichawack River, the line was to "run north two degrees west till 120 miles were finished . . . or until it meets with His Majesty's other governments."[28] A portion of this line was "spotted and measured" in 1741, a continuance in 1767, and the remainder in 1789.

It was claimed by Massachusetts, with seeming justice, that the first surveyor did not make due allowance for the variation of the compass. It is probable the other two did not correct for annual change in the variation. All three let topographic features influence mildly the position of the line, according to their convenience. So it will be seen the marked line only approximates the loxodrome described in the early papers.

Other examples of the loxodromic boundary in New England, are found in short portions of the Connecticut-New York line in the Sound. Here they are referred to as "a true southeast course" (23), "east three-quarters north, sailing course" (32), etc. Other varieties of expression for the loxodrome are "a line to be run north 45 degrees east" till it intersects a specified river, as in the description of the Virginia-Kentucky boundary; and "from Goat Island northwest to the 35th degree parallel," as in that of the North Carolina-South Carolina line.

The loxodrome is not used nearly so often as a boundary as are the other mathematical lines mentioned above. When it is used in documents the engineers in the field, either through ignorance

[28] New Hampshire Historical Collections, Vol. 2, p. 278.

or for mutual convenience are likely to convert it into a straight line, or a broken line made up of a series of straight lines which approximate the true curve.

Arcs of Small Circles.—This class of mathematical boundaries has no representative in the boundaries of the New England States, but is considered here to round out the class, and because it is an interesting member of the group. As a boundary line a small circle may be defined as a circular arc of small radius, which has for its center a natural or artificial object.

The only state boundary in the Union that includes a circular line is that of Delaware-Pennsylvania. It is described as "an arc of a circle, having for its center the steeple of the old court-house at New Castle, Delaware, and a radius of twelve miles."[29] This circular boundary of a state was evolved from a county line which was described in a conveying deed as "the town of New Castle and a twelve-mile circle around the same."[30] Later Delaware was formed by the union of three counties, one of which was New Castle.

The work of running the line was done years after its definition, and was attended by many surveying difficulties. Such a line in order to be recognized has a unique disadvantage as a boundary, in that it requires an almost continuous visible indication of its course.

The circular boundary is used in the United States very sparingly for town boundaries. Some of the old Hanse towns of Germany were bounded by circular lines.

The study of the mathematical boundaries of New England has shown that, in general, they can be easily expressed in treaties, even in reference to a country that is little known. This explains why they are so common in the United States, Canada, Africa, and Australia. Mathematical boundaries can also be easily identified on a map; they can be definitely located on the ground; and, unlike some river boundaries, their courses can be precisely marked by monuments.

Their one great drawback, and this is vital, is that unless they are carefully related to the topography, they are almost certain to create political divisions in ethnic, physical, industrial, and perhaps religious units, and this may be a basis for strife. Hence the mathematical boundary, especially if it is international, is liable to undergo changes until it becomes more harmonious with the surroundings. This may be one reason why there are so few boundaries of this type in Europe and Asia.

29 Henry Gannett, Boundaries of the United States (3d Edition), *Bull.* 226, *U. S. Geol. Surv.*, p. 86.

30 *Ibid.*, p. 87.

BOUNDARY MARKS.—Some of the marks by which the courses of the early boundary lines of New England were indicated were indeed crude and inadequate. Yet some of these are still extant as the only authoritative marks. The loxodrome boundary of the Maine-New Hampshire line illustrates the matter. A part of the record reads: "thence same course two hundred twenty-five rods across a bay of said lake; thence same course two hundred six rods across a peninsula of the same; thence same course . . . across the north bay of said lake, to a cedar post marked "N." "M." . . . thence same course one hundred sixty-two rods to a spruce . . . thence . . . to a perpendicular precipice; thence same course . . . to a beaver pond; thence same course . . . to a yellow birch on the highlands."[31]

It will be easily seen how forest fires, clearings by man, and destruction by natural agencies would soon make such a record nearly worthless. It was such a description of a boundary line that made Rufus Choate exclaim, "I would as soon think of setting forth the boundaries between sovereign states as beginning at a blue jay on the bough of a pine tree, thence easterly to a dandelion gone to seed, thence due south to three hundred foxes with firebrands tied between their tails."[32]

EFFECT OF BOUNDARIES ON PEOPLE WHO LIVE NEAR THEM

CONDITIONS NEAR BOUNDARIES.—The effect of a special geographic feature such as a boundary may be clearly seen in the people who live near it, especially if the line is undetermined, ill-defined or disputed. This is well illustrated in the history of the Sound boundary between Connecticut and New York. Before the definite establishment of this line, many of the islands in the Sound were used as convenient resorts by persons wishing to engage in illegal trades or practices, since an arrest under authority of either state might be met by a claim of jurisdiction of the other. The following citations of illegal proceedings in relation to this region are abridged from the New Haven Historical Society Papers, Vol. III.

On one occasion, a party of prize fighters and spectators from New York landed on one of the questionable islands to have an encounter. A company of Connecticut militia was levied, rushed to the scene of combat, and captured the whole party. The counsel of the prize fighters took exception to the jurisdiction of the Connecticut courts on the ground that the acts complained of were committed in New York, and the cases were never brought to trial.

[31] *Ibid*, p. 43.

[32] W. Harriman, History of Warner, N. H., p. 553.

A case of piracy occurred on a schooner lying a distance from shore in the Sound. The offender was seized, tried and convicted, but the Supreme Court of the United States arrested the sentence of death, because it was doubtful whether the spot where the schooner lay, was or was not within the jurisdiction of New York. A second trial resulted in the pirate's discharge, because the jury were of the opinion that the act was done outside the jurisdiction of the court which tried him.

Thefts and assaults occurred on the many steamers and other crafts plying the Sound, and it was always questionable in what jurisdiction they were to be deemed committed,

The notorious pirate, Captain Kidd, used a small group of the Sound Islands as his haunt because of their inviting position in relation to the unsettled boundary.

Previous to 1853 the boundaries of Massachusetts included a small district in the southwestern corner, called Boston Corner, that was separated by rugged highlands from the rest of the state. For obvious reasons, this became a resort for desperadoes. This condition finally brought about its transfer to the neighboring state of New York.

The more usual activities of people near boundary lines, take the form of evasion of taxes and license laws, illegal voting, and the like. To facilitate the evasion of laws hotels are often built along the line. Experience with this condition led the United States commissioners of the U. S.-Mexico Boundary Commission to recommend that a reservation of not less than fifty feet be declared by the United States to extend along the entire length of the boundary on the American side, and that the Republic of Mexico be asked to declare a like reservation on the Mexican side, and that the erection of buildings on either side, within these limits be prohibited.

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THE INFLUENCE OF LAKE MICHIGAN UPON ITS OPPOSITE SHORES, WITH COMMENTS ON THE DECLINING USE OF THE LAKE AS A WATERWAY

RAY HUGHES WHITBECK

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INTRODUCTION.—Lake Michigan, three hundred miles in length and nearly one hundred miles wide, projecting into the very heart of a rich territory, has notably influenced the location of cities and industries, the direction of railways, and the distribution of population and wealth on the west side; and it has made the east shore one of the summer play grounds of the Middle West, and one of the important fruit belts of the nation.

CLIMATIC CONTRASTS.—Lake Michigan influences air temperatures—especially the maximum and minimum temperatures—for some twenty miles inland from its eastern shore. The heat stored up in summer in the waters of Lake Michigan is given off in autumn and early winter to the prevailing westerly winds and is carried over western Michigan. During the spring the water warms much more slowly than the land; the winds blowing across the lake are cooled and give the shore lands of Michigan a lower temperature than would prevail were the lake not present. This retards the spring, prevents vegetation from responding too promptly to the early warmth, and largely explains the high development of fruit growing on the Michigan side of the lake.

The rainfall on the Michigan side differs little in quantity from that on the Wisconsin side, but the amount of snowfall and the character of the storms are considerably modified. Lansing in the interior of Michigan has, on an average, forty-two thunder storms per year, while Grand Haven on the Lake Michigan shore averages but twenty-six.[1]

[1] Seeley, D. A., The Climate of Michigan and Its Relation to Agriculture, in Rept. Michigan Board of Agriculture, 1917, p. 694.

The shore counties receive from ten to twenty inches more snowfall than the interior counties, and considerably more than the Wisconsin shore counties receive. The effect of the diminished number of thunder storms on the Michigan shore of the lake is mainly of importance as it favors the numerous summer resorts of this region.

The Michigan shore has a higher percentage of sunshine in summer and a higher percentage of cloudiness in winter than the Wisconsin shore opposite.[2] Both the summer sunshine and the winter cloudiness are favorable to fruit growing. One cause of the winter-killing of fruit trees is the desiccation of the wood of the tree leading to the impairment of its strength, and often to its death. If the winters are moist, resulting from a high degree of cloudiness, the injurious desiccation of the wood is prevented, and winter-killing is greatly reduced. It is believed that this is one of the important climatic differences which make fruit growing on the Michigan side far more prosperous than on the Wisconsin side of the lake.

Grand Haven in Michigan lies directly opposite Milwaukee. Its mean January temperature is four degrees warmer than that of Milwaukee, and six degrees warmer than that of interior cities of Wisconsin and Iowa in the same latitude. The January minimum is ten degrees higher at Grand Haven than at points in the interior of Wisconsin and Iowa in the same latitude.[3] The January isotherms of 15° and 20° are bent northward over 400 miles by the influence of the lake. The extremely low winter temperatures which visit Wisconsin are never so severe on the Michigan shore; when it is twenty-five below zero at Milwaukee and thirty below in Madison, it may be only fifteen to eighteen below in Grand Haven.[4]

A corresponding influence of the lake is seen in the summer temperatures. The east shore of Lake Michigan is six to ten degrees cooler during hot waves in summer than is the interior of Michigan. During one of the hottest months on record, July of 1916, the official temperature in the interior of Michigan reached 106°, while along the Lake Michigan shore it was from five to ten degrees cooler (Fig 1). This is another of the reasons for the development of summer resorts on this shore.

The influence of the lake in the northern part of the southern peninsula of Michigan is unusually great. The shore counties have a growing season of one hundred and sixty days as far north as Manistee,

[2] "In January, the actual sunshine in western Michigan is less than 20 per cent of the possible amount." Seeley, *ibid*, p. 697. The *Monthly Weather Rev.*, Jan., 1920, p. 16, gives average for Jan. 1905-12 at Grand Haven as 24 per cent, and Milwaukee, directly across the lake, as 44 per cent.

[3] Seeley, *ibid*, p. 692.

[4] Seeley, *ibid*, p. 693.

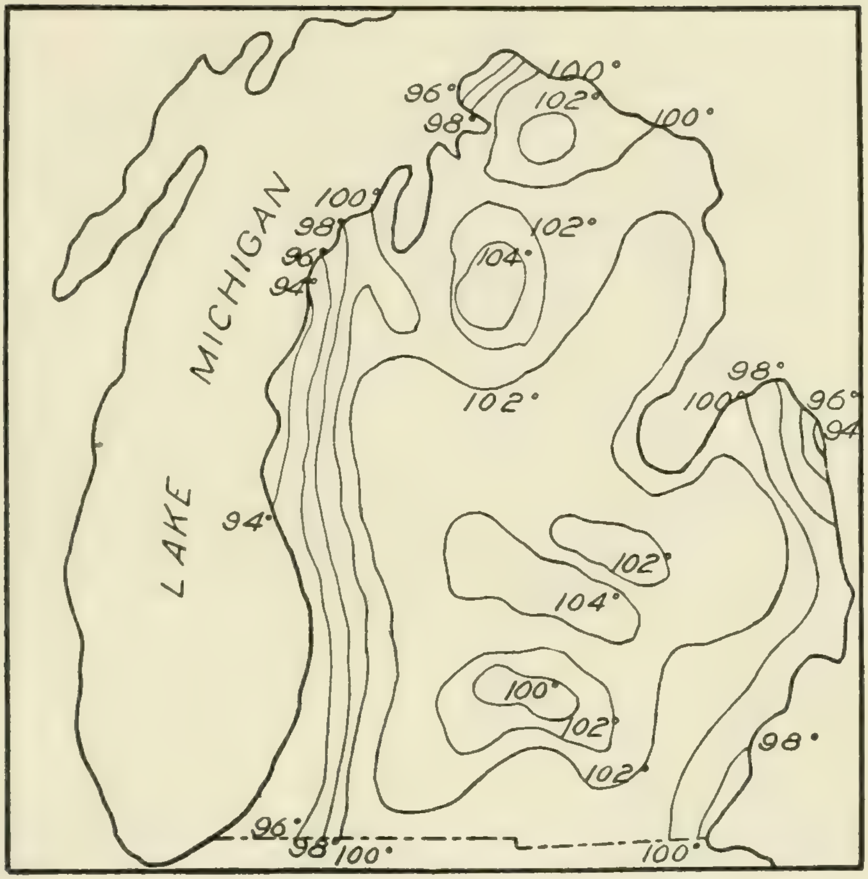

FIG. 1. Isotherms, July 1916—one of the hottest months on record. Note the cooling effect of Lake Michigan. (After Seeley.)

while in the interior of Michigan seventy-five miles east, the growing season is only one hundred days in length[5] (Fig. 2). The difference in altitude is sufficient to cause only a few degrees difference. In January, Manistee has the same mean temperature as Detroit, one hundred and thirty miles farther south. During one of the coldest recorded months (January, 1912), the lowest temperature along the entire Lake Michigan shore of Michigan was —10° F.; while the counties of the southern interior had —20°, and those of the northern interior—35°.[6] It is evident that the effect of Lake Michigan upon the climate of the Michigan shore is marked (Fig. 3).

[5] Seeley's map, Chart XIII, p. 705, shows a small area where the average growing season is only 90 days long. The Atlas of American Agr., Part II, Sect. I, p. 12, shows this region to have a growing season of 90 days in four-fifths of the years.

[6] Seeley, *ibid*, p. 692.

Fig. 2. Length of the growing season in days for Lower Michigan. (After Seeley.)

Fruit Growing.—The accompanying map showing the number of orchard trees in the counties bordering on Lake Michigan in Wisconsin and in Michigan brings out the lake influence impressively (Fig. 4). The Lake Michigan shore counties of Michigan make up one of the important fruit belts of the United States, while fruit growing on the Wisconsin side is only an incident. For example, Van Buren County in Michigan has 550,000 orchard trees, Oceana 600,000, Allegan 800,000, and Berrien nearly 1,000,000; while the highest number of orchard trees in any shore county in Wisconsin is in Sheboygan, 130,000. Berrien County, Mich., produces 50,000,000 pounds of grapes in a good year, while no county on the Wisconsin side of the lake produces even 30,000 pounds. A single county on the Michigan side produces 8,000,000 quarts of small fruits a year, while the highest production on the Wisconsin side is less than one-sixteenth

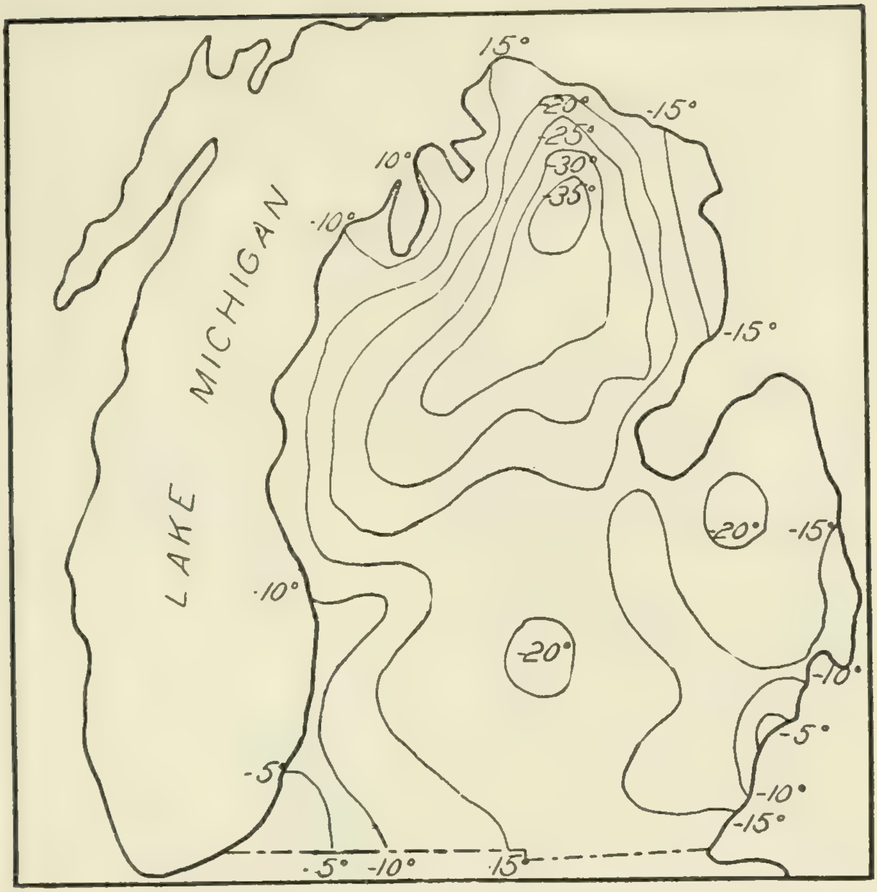

FIG. 3. Isotherms for January, 1912—one of the coldest months on record in Lower Michigan. (After Seeley.)

as much. The most striking difference is seen in peach growing. This has not maintained its former importance in Michigan; yet in 1910 many counties of Michigan produced from 100,000 to 200,000 bushels of peaches, while all the counties on the Wisconsin shore produced only a few hundred bushels.[7] In short, peach growing has been an important industry in Michigan, while just across the lake in Wisconsin it has never attained even incidental importance.

SUMMER RESORTS.—There are at least 40 cities and towns along the Michigan shore of the lake in which summer hotels and a general development of summer resort activities have attained prominence. Several towns on the Michigan side have from five thousand to ten

[7] Data from U. S. Census of 1910.

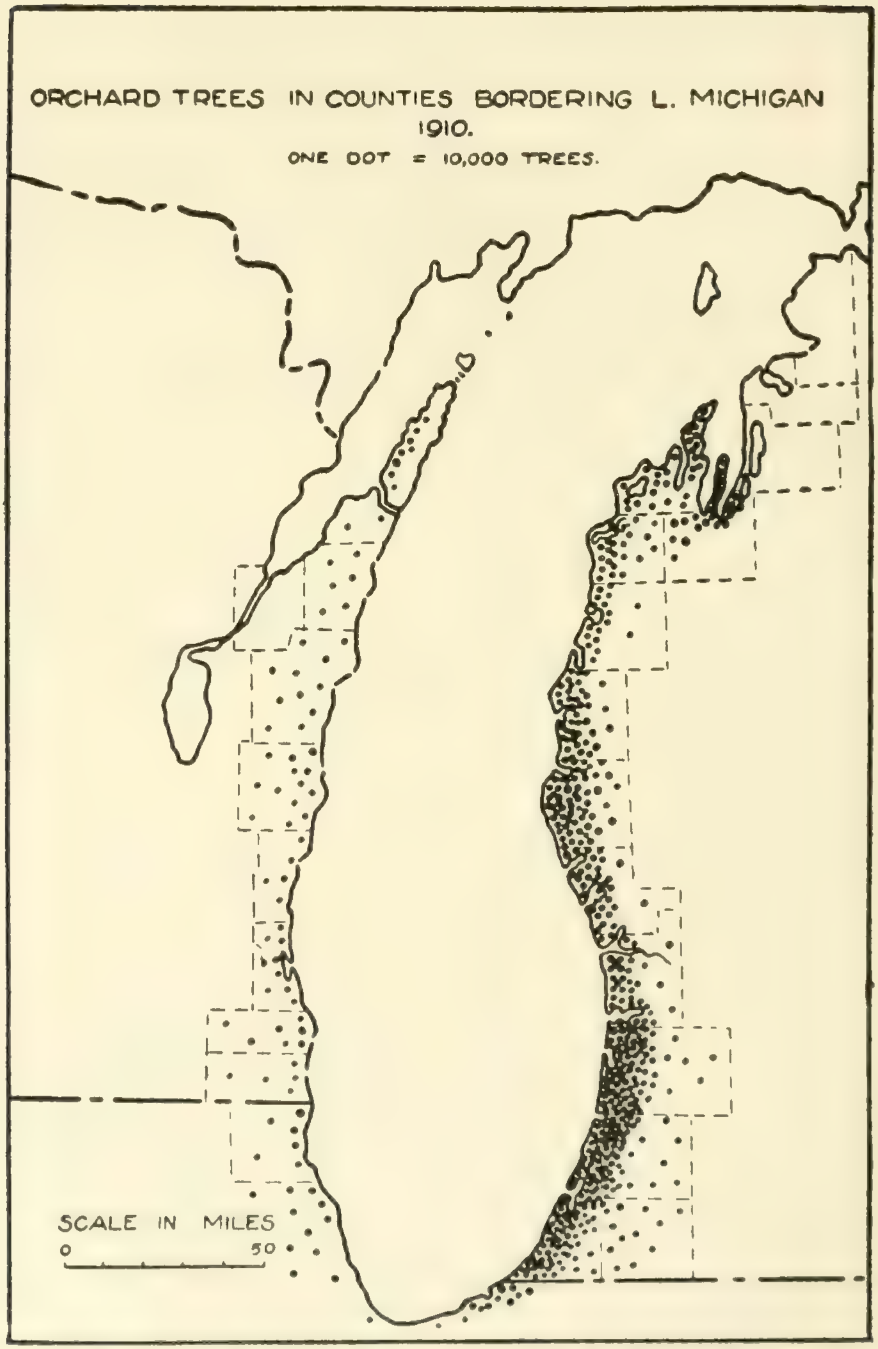

FIG. 4. Relative importance of fruit growing on the opposite sides of Lake Michigan.

thousand additional summer residents, and some of these towns entertain from fifty thousand to one hundred thousand transient visitors during the summer. Figure 5 shows the number of passengers taken by steamers in 1914 to various cities along the shore of Lake Michigan. On the Wisconsin side the only city receiving any considerable number of passengers by lake boat was Milwaukee and very few of these were summer tourists. The prevailing westerly winds, blowing across the lake, cool the Michigan shore in summer from five to ten degrees, and this is sufficient to give Michigan its advantage over the Wisconsin shore of the lake in attracting summer visitors.

Population and Industry.—Between 1840 and 1860, when home seekers were pouring into the Middle West, the Great Lakes formed one of the chief routes of westward movement. The settlers could land at points on Lake Michigan either in Michigan or in Wisconsin. The two sides of the lake had equal opportunities for securing settlers. Both sides of the lake have had an equal length of time in which to acquire population and develop industries; yet the Wisconsin shore counties have attained three times the population and a far greater industrial development. This has resulted in a much greater accumulation of wealth here than on the Michigan side. The barricade of sand dunes along the Michigan shore (due to the prevailing direction of the wind) was not an attraction to home seekers. In these comparisons no account is taken of Chicago, which is, to all intents and purposes, at the southern end of Lake Michigan, and is therefore disregarded in comparing the eastern and western shores of the lake.

Of the largest ten cities in Michigan only one is on the shore of Lake Michigan, and this one, Muskegon, is the smallest of the ten. Of Wisconsin's largest ten cities, five are on Lake Michigan and one of these has a larger population than all of the cities and towns in Michigan on the Lake Michigan shore (Fig. 6). In Wisconsin the most marked concentration of population and industries is along the shore of Lake Michigan, while no such concentration exists on the opposite side of the lake.

Influence of Lake Michigan and the Mississippi River Contrasted.—The influence of the Lake Michigan waterway upon Wisconsin may be contrasted with the influence of the Mississippi River, on its western boundary. In 1910 (the last published census), the average valuation of all property per square mile in the counties adjacent to the Mississippi River was about $47,000, while the average valuation per square mile of the lake shore counties was nearly $200,-000, or four times as much. For the counties south of Door County the

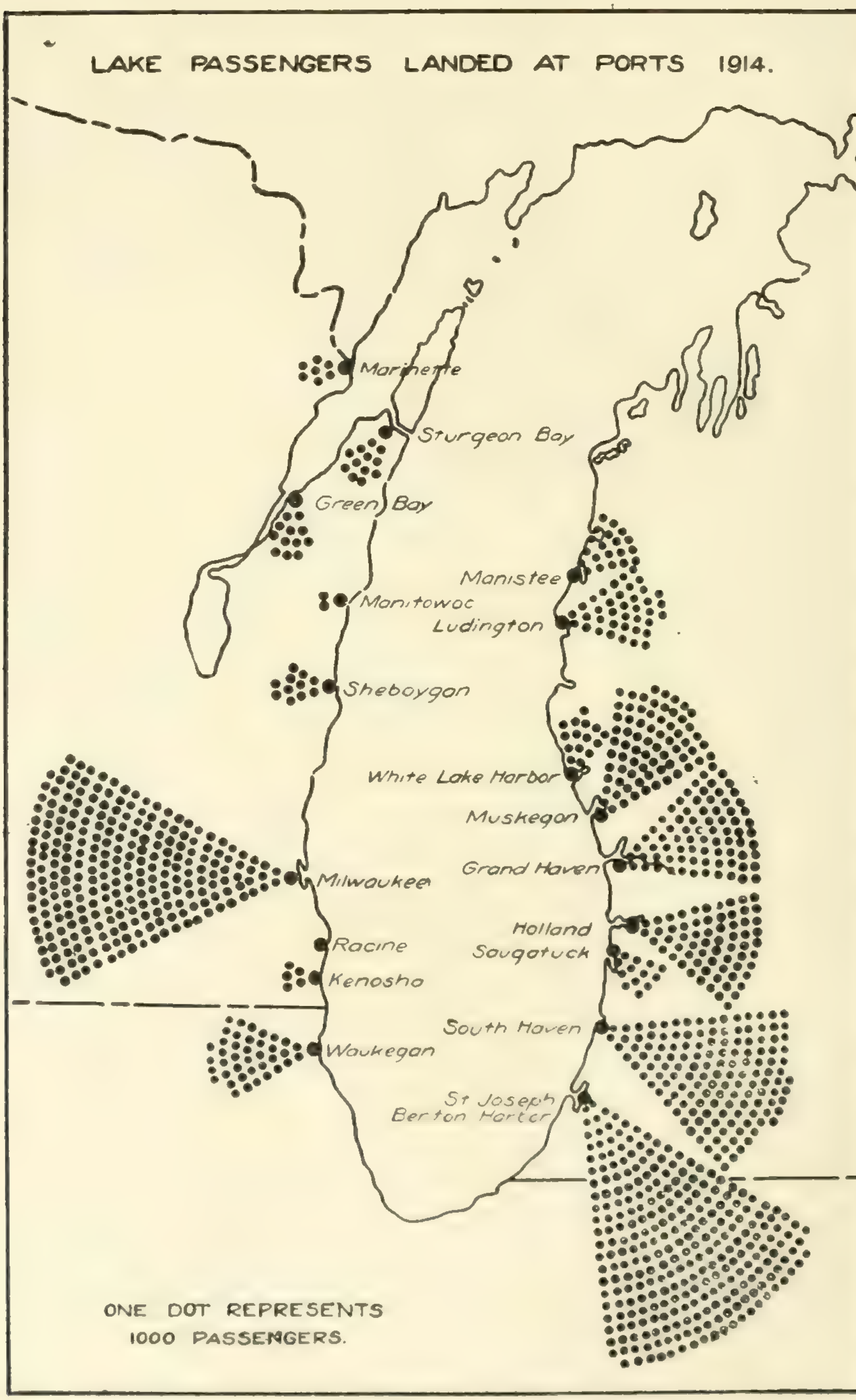

Fig. 5. Passengers landed at Michigan ports—mostly tourists, except at Milwaukee.

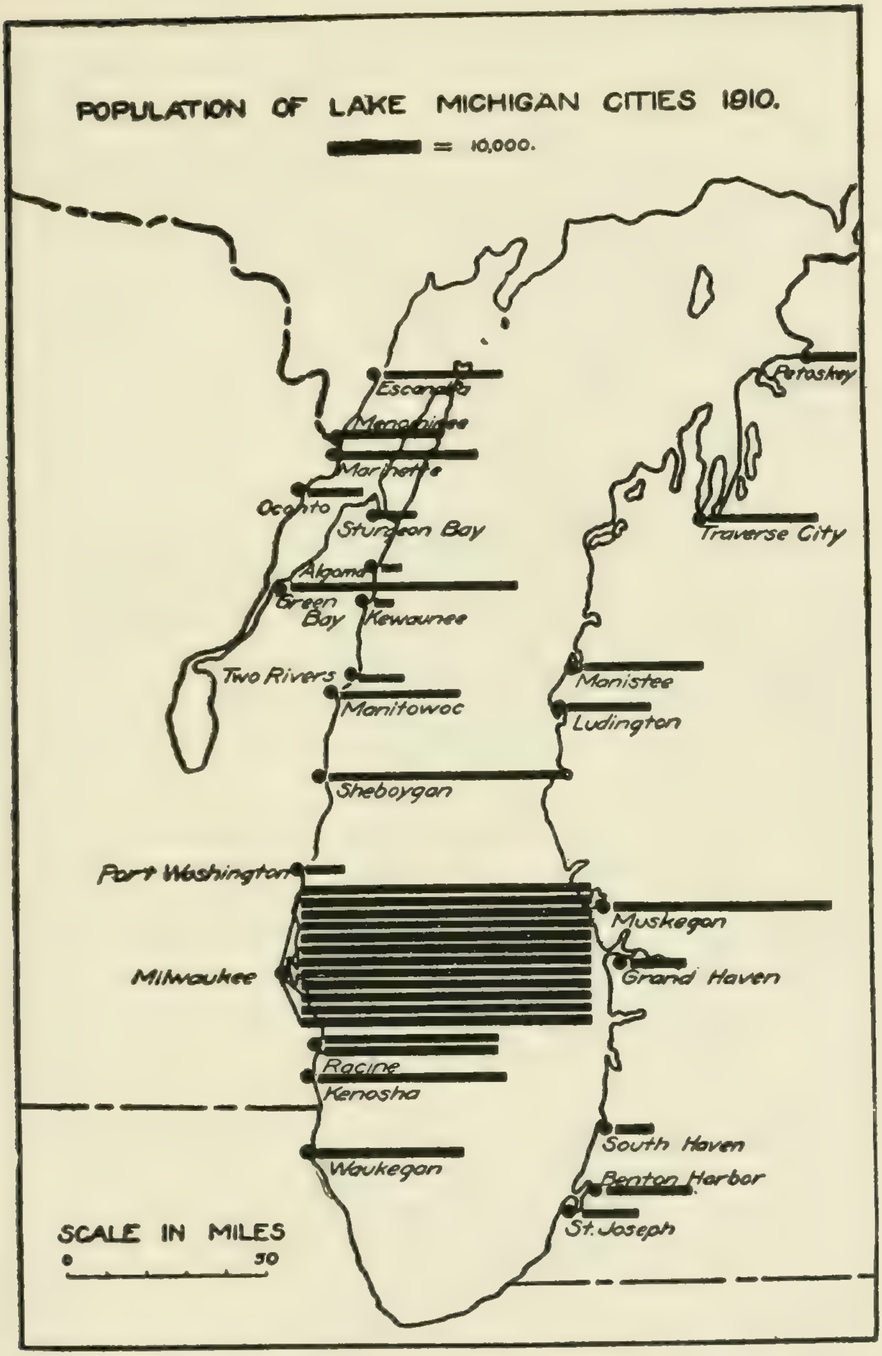

FIG. 6. Population of Lake cities in Michigan and Wisconsin.

average valuation rises to over $400,000 per square mile, and in the three southernmost lake shore counties, the valuation rises to $1,000,000 per square mile.[8]

Lake Commerce.—The chief movement of products from both Wisconsin and Michigan is toward the east. The water gates through which the products of Wisconsin pass eastward are those of Lake Michigan, while in Michigan they are those on the eastern side of the state; hence the lake ports of western Michigan have practically no hinterland. Incoming lake traffic enters Michigan from the east and Wisconsin from the east. This has given a large importance to the Wisconsin ports on Lake Michigan but practically no importance to those of Michigan. This idea is emphasized by the drawing showing the freight movements in and out of Lake Michigan ports (Fig. 7). Aside from Ludington and Grand Haven, there is practically no freight movement in or out of the ports on the east shore of the lake. These two cities are the termini of car ferries from Kewaunee, Manitowoc, and Milwaukee, and the freight movements to these ports are almost entirely through-freight destined to eastern markets. With the exception of the car ferry traffic the freight movements in and out of the Michigan harbors of Lake Michigan are negligible, while those on the Wisconsin side rise to millions of tons annually; yet as will appear later, the relative importance of traffic on Lake Michigan, except in coal and grain, is declining.

Development of Manufacturing.—Half of all the manufacturing done in Wisconsin is done in six cities on the shore of Lake Michigan. Aside from lumber and salt there has been very little manufacturing on the Michigan side of the lake. Not one city, excepting Muskegon, can be called a manufacturing city, while Kenosha, Racine, Milwaukee, Manitowoc, Sheboygan, and Green Bay in Wisconson are all distinctly manufacturing centers deriving most of their advantage of location in the past, at least, from their position on the lake.

The Declining Importance of Lake Traffic on Lake Michigan.—During the first half century of statehood, the importance of Lake Michigan to the industries of Wisconsin was very great but that influence has diminished relatively during the past twenty years, and has declined absolutely during the last ten years. The Wisconsin cities on the lake shore owe their start and their industrial momentum to the lake, but these same cities have grown most rapidly during the past two decades and during these decades lake transportation has declined in relative importance so far

[8] Data from U. S. Census of 1910.

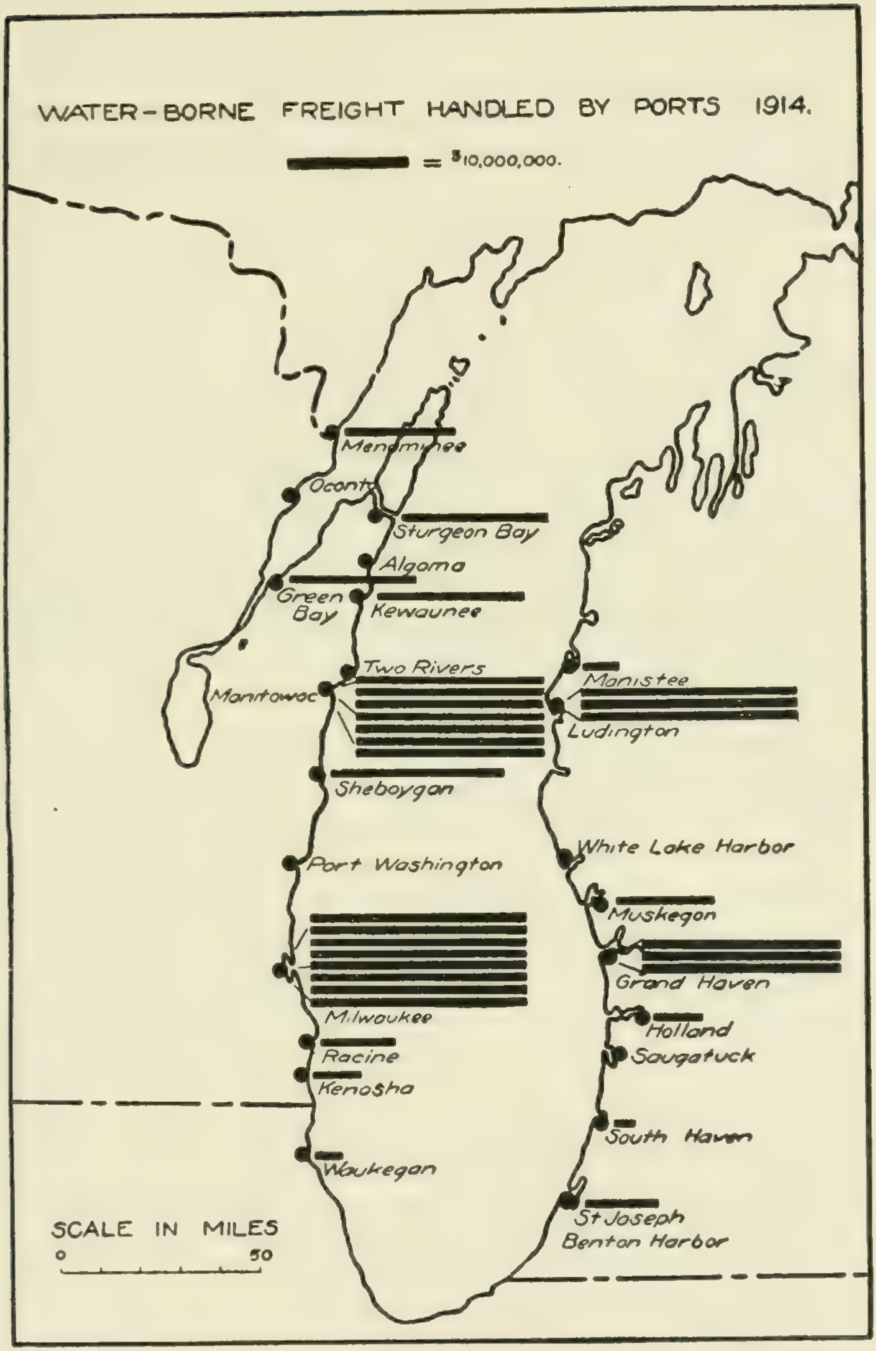

FIG. 7. Contrast of water borne traffic handled by ports in Michigan and Wisconsin.

as Wisconsin is concerned. The only incoming freight of importance is coal, both hard and soft, from Lake Erie ports. If hard coal is to be used in Wisconsin it must come from Pennsylvania, and about $2.00 a ton is saved in freight charges if it comes by lake. Soft coal can be obtained by rail from Indiana and Illinois as cheaply as eastern soft coal can be obtained by rail and lake, and more cheaply in the case of a large part of the state.

Car Ferries.—Car load shipments from the northwest destined for eastern markets can in many cases save time by crossing Lake Michigan on car ferries, thus avoiding the haul around the south end of the lake and also the congestion which often exists at Chicago. Fifty per cent of the lake shipments from Milwaukee and twelve per cent of the receipts by boat use the car ferry. To such shipments the lake is a disadvantage for the ferry is simply a form of bridge by which railroad traffic crosses the lake. This increases the cost of handling freight. Were the lake not here the rail lines would cross the area now occupied by the lake at less cost and greater speed than is now the case. Three car ferries connect Milwaukee with Ludington, Muskegon, Grand Haven, and South Haven; and Manitowoc and Kewaunee, with Ludington and Frankfort.

Increasing Importance of Rail Traffic.—Prior to the Civil War a major part of the general freight received at and shipped from the Lake Michigan cities was carried by lake boats. Regular lines of steamers ran to Lake Erie ports and to other ports on Lake Michigan. Great numbers of passengers and large quantities of freight of all kinds came and went by lake steamers and schooners. Today Milwaukee is the only Lake Michigan port in Wisconsin that receives or ships any considerable amount of commodities except coal by lake. Eighty per cent of the incoming freight at Milwaukee is coal from the East and over fifty per cent of the outgoing freight is grain.[9] Both of these commodities are handled in full cargoes, are loaded and unloaded by special machinery, and are carried long distances, usually 800 miles or more. Under such conditions, lake transportation is cheaper than rail. Yet it is noteworthy that receipts of coal by boat at Milwaukee, Racine, and Kenosha are declining and those by rail are increasing. It is to be noted that whereas iron ore and coal shipped by the lakes average scarcely one mill per ton mile, the miscellaneous products shipped short distances (in 1917) averaged over 7c a ton mile, or 70 times as much.

[9] Report of Milwaukee Harbor Commission, 1919, pp. 24, 25.

Manufacturing in these lake shore cities of Wisconsin has increased very rapidly in recent years, but the increased business is practically all being handled by the railroads. So far as these cities are concerned very little freight is handled either by boat lines connecting with the lower lakes or by along-shore lines. For example, only four per cent of Milwaukee's tonnage of lake freight is carried by along-shore steamship lines, and only three per cent by regular lower lake lines.[10] The along-shore traffic is almost wholly package freight carried by three or four steamers which ply between Milwaukee and Chicago, one line calling at Racine and one at Kenosha. These along-shore steamers impose practically the same freight charges as do the railroads, but merchants or manufacturers in Milwaukee or Racine can order articles from Chicago and get them more promptly by boat than by rail. The saving is in time rather than in cost.

Milwaukee, Racine, and Kenosha receive large quantities of material and ship great quantities of manufactured goods; yet very little of either goes or comes by lake. A few specific examples may serve to illustrate how little use manufacturers are now making of lake transportation. The largest manufacturing concern in Racine is the J. I. Case Threshing Machine Company, makers of threshing machines, tractors, automobiles, and farm machinery. Their main plant is on the harbor of Racine and their new South Plant is on the lake shore; yet during the past summer the company was making no use of the lake for transportation. Even the coal came by rail; and the steel, which is made by the Illinois Steel Company of Milwaukee, also on the lake shore, came by rail. At present nothing is shipped away by boat. Moreover, the Illinois Steel Company of Milwaukee gets most of its pig iron and steel billets from Gary, which is also on Lake Michigan; yet even these heavy commodities are shipped by rail.

One of the largest concerns in Kenosha, the Simmons Manufacturing Co., owns a large part of the water frontage of Kenosha harbor, having its own docks; yet it receives none of its coal or raw materials by lake and ships all of its products, amounting to 8,000 cars a year, by rail.

It is a matter of some surprise that, though the United States government has expended nearly as much money on Racine and Kenosha harbors from 1910-1916 as in all previous years combined, yet the lake traffic (except coal) has declined to a negligible amount and even coal receipts are declining.

It is disconcerting to find that a great natural waterway like Lake Michigan, with such large cities as Chicago and Milwaukee and several smaller but rapidly growing cities on its shore, seems to be actually declining in usefulness. The traffic in and out of Milwaukee harbor is

[10] *Ibid*, p. 23

less than it was ten years ago and that in and out of Chicago harbor is less than half what it was in 1905, although the tonnage—chiefly iron ore—entering South Chicago harbor has increased. At the same time the rail traffic parallel to the shore of Lake Michigan has increased with great rapidity. Three double track steam lines, one single track steam line and an electric line, or eight tracks in all, connect Milwaukee and Chicago. On these lines there is a constant succession of trains; yet one may sit on the shore of the lake all day and see only occasionally the smoke of a passing steamship. A resident of Racine told me of taking a trip by boat from Kenosha to Racine in the early eighties and counting 60 lake boats in traveling this distance of ten or twelve miles. Another man told of seeing 80 lake boats tied up for the winter in Racine harbor. Not one-tenth as many would now be seen, though the boats in use at present are larger than those used in the past.

The improvement of waterways, often urged as a means of relieving congestion on railroads, seems of questionable aid in case of waterways that are closed by ice all winter when congestion most often occurs. During the late war when transportation lines were strained as never before, the Great Lakes were used slightly, but only slightly, more than in normal times and availed little, if at all, in relieving rail congestion, and the same has been true since the war. Owing to the sale of lake steamers to foreign buyers in the first years of the war, our lake fleet was reduced and service was already curtailed when we entered the war and most needed it. Owners of lake boats have no hesitation in discontinuing service whenever it is to their interest to do so. In recent years there has been a constant decline in this service along the Wisconsin shore of Lake Michigan. Shippers can not count on permanence of freight service by lake boats, for the boat owner will sell his boat or transfer it to another route if he chooses. Railroads give a far better guarantee of regular and permanent service, and rates are controlled by state or government commissions. Railroads operate the year round and railroad spurs may be built to the very doors of the factory. One is led to ask, if water traffic on a great natural waterway like Lake Michigan is not able to maintain itself except in a few special commodities, what must happen to traffic on rivers and canals?

Conclusion.—The influence of Lake Michigan upon its two shores has been very different indeed. On the Michigan side it is mainly a matter of climate, resulting in a high development of fruit growing and of summer resorts. On the Wisconsin side neither of these developments has taken place, but the lake has induced a very marked concentration of population, wealth, industry, and commerce. There has been little development of urban centers on the Michigan side, but a very notable development in Wisconsin. None of the cities on the east

side of the lake are railroad termini of importance. All of Wisconsin's important railroad termini are on Lake Michigan, and all but one of its more important early railroads were built inland from points on the lake. The high point of Lake Michigan's influence in the industrial development of Wisconsin was in the past. To this there is one marked exception; that is the advantage to the lake shore cities in securing coal from the East. In short, Lake Michigan has been only a minor factor in the industrial life of Michigan, but it has been in the past a very large influence in that of Wisconsin. However, when the present is considered, water transportation seems to have very little to do with the great industrial development which is taking place in the Wisconsin cities on Lake Michigan. Even the receipts of coal by lake are declining, while the great quantities of heavy material passing between Gary, Chicago, Milwaukee, Racine, and Kenosha, are practically all carried by rail, and this in spite of the fact that many of the largest manufacturing plants that ship or receive these heavy commodities are themselves on the water front. The cause seems to lie in the fact that railroad service is usually more dependable, and more convenient, operates twelve months in the year, and costs little if any more, except in the case of cargo shipments of bulk commodities carried long distances, as is the case with iron ore, coal and grain.

References

Day, P. C. Frost Data of the United States, U. S. Weather Bureau, Bull. V, Washington, D. C.

Eshelman, C. H. Climatic Effects of the Great Lakes as Typified at Grand Haven, Mich. Pamphlet, 1913.

Finch, V. C. and Baker, O. E. Geography of the World's Agriculture, U. S. Dept. of Agr., Washington, D. C., 1917.

Gannett, Henry. Distribution of Rainfall, Water Supply Paper 234.

Henry, A. J. Winds of the Lake Region, Mo. Weather Rev., Nov., 1907, p. 506.

——— Climatology of the United States, U. S. Weather Bureau, Bull. Q.

Miller, Eric R. The Meteorological Influence of Lakes, Proc. Pan Am. Sci. Cong., 1915-16, Vol. II, pp. 189-198.

Reed, Wm. G. Frost and the growing season; in Atlas of Am. Agr., Part II, Sect. I.

Seeley, D. A. The Climate of Michigan and its Relation to Agriculture, Ann. Rept. Mich. Board of Agr., pp. 683-715, Lansing, 1917.

Whitbeck, R. H. Industries of Wisconsin and their Geographic Basis, Annals Assoc. Am. Geographers, 1912, Vol. 2, pp. 55-64.

——— The Geography and Industries of Wisconsin, Bull. 26, Wis. Geol. Survey, Madison, 1913.

——— The Geography and Economic Development of Southeastern Wisconsin, Bull. 58, Wis. Geol. Survey, Madison, 1921.

Whitson, A. R. and Baker, O. E. The Climate of Wisconsin and its Relation to Agriculture, Bull. 23, Agr. Exp. Sta., Univ. of Wis., Madison, 1912.

Wood, L. H. Geography of Michigan, Kalamazoo, 1914.

Milwaukee Harbor Commission, Annual Reports of, Milwaukee, Wis.

Milwaukee Chamber of Commerce, Annual Reports of, Milwaukee, Wis.

U. S. Army, Chief of Engineers, Annual Reports on Harbors of the Milwaukee District, Washington, D. C.

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WEATHER CONDITIONS AND THERMAL BELTS IN THE NORTH CAROLINA MOUNTAIN REGION AND THEIR RELATION TO FRUIT GROWING

HENRY J. COX

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Introduction.—A research of the thermal conditions in the North Carolina Mountain region was inaugurated in 1912 by the speaker, in behalf of the United States Weather Bureau, and at the request of the North Carolina State Board of Agriculture and the State Horticulturist, with a hope that the so-called Thermal Belts might be more clearly defined, and that safe elevations for the planting of fruit trees might be determined, as far as possible, in the various sections.

Considerable success had been attained in many portions of that region in the growing of hardy fruit, especially apples, but here and there marked failures had occurred, supposedly because of either too great altitude or unfavorable topography, inducing freezes in the one case and severe frosts in the other.

Heretofore, the planting of orchards in the mountain region had been carried on in a rather haphazard way, so far as the influence of temperature conditions was concerned, and it was believed by the State Horticulturist that an exhaustive study of the various problems might furnish valuable information for the guidance of orchardists in the development of their properties.

Reference has frequently been made in meteorological and climatological literature to thermal belts or frostless zones in mountain districts, both in this country and in Europe. These belts of varying width in which frost is never observed were said to be found on certain slopes between the valley floor and the summit, their development being due mainly to the fact that during certain cool nights the temperature is relatively high on the slope—much higher than at the base.

This phenomenon, termed an inversion of temperature, is observed most frequently on clear quiet nights, but sometimes on partly cloudy

and even cloudy nights. It is called an " inversion " because ordinarily we expect a lapse in temperature with elevation, which, for the want of a better name, we may here term a " reversion," in contrast with the term " inversion." On the average, the temperature of the free air falls with height, the mean rate of decrease being 1° F. in 300 feet of ascent; and there are many nights in the mountain region when this decrease in temperature with elevation is observed, sometimes greater even than the average rate, especially when the weather is cloudy and windy. There are still other nights, moist and damp, when the differences in temperature between various elevations are hardly appreciable.

Both inversions and reversions are quite pronounced on mountain slopes of considerable vertical height and are important factors in the question of fruit-growing. In the one case the minimum temperature is lowest at the base and highest at some point on the slope or at the summit, while in the other case the minimum is lowest at the summit and highest at the base; and, through a combination of these two conditions, we sometimes have a belt more or less indefinite in width where the minima average higher than at either the base or the summit, free from the frosts of the valley and from the freezes of the higher levels. Within this belt, which has been called a " verdant zone," the foliage is frequently fresh and green as compared with that above and below.

Description of Region.—More has probably been written regarding thermal belts in the North Carolina mountains than in any other section of the country, doubtless because the phenomena are more pronounced there than elsewhere in the east, on account of the more extensive slopes and the greater area.

The Appalachian Mountains, which form the divide between the great central valleys of the United States and the Atlantic Plain, extend in a southwest direction from Pennsylvania to northwest Georgia, but the culminating section of the system lies in western North Carolina. While the elevation of the Atlantic Plain at the base of the mountains is only 150 feet in Pennsylvania, and perhaps 500 feet in Virginia, in North Carolina it rises to about 1,000 feet.

The Appalachians divide into two chains in Virginia, one, known as the Great Smokies, continuing in its southwesterly course and forming the boundary of western North Carolina; and the other, retaining the name of the Blue Ridge, as the range in the north is called, crossing the state farther eastward and forming the great watershed of the drainage of that section. Between the two chains lies a remarkable region of valleys and plateaus, at no point falling to a lower elevation than 2,000 feet, while portions of the plateau in Watauga County to

the north and Macon County to the south have an elevation as high as 4,000 feet. Within this system, scores of mountain peaks rise to an altitude of more than 5,000 feet, and many even more than 6,000 feet, Mt. Mitchell being the highest with an elevation of 6,711 feet.

The North Carolina mountain region, then, is preeminently a land of high mountains and plateaus; and because of its elevation, it is known as the "Land of the Sky," a region most irregular in shape, having an area of over 5,000 square miles, and extending in a northeast and southwest direction about 125 miles.

In a general view, the eastern chain, or Blue Ridge, is seen to be irregular and fragmentary, while the western chain, the Great Smokies, is more regular, elevated, and continuous. Nevertheless, the drainage of the plateau between the two is thrown entirely to the westward. Numerous cross chains uniting the main ranges form basins which contain the mountain tributaries of the Tennessee River. Projecting into the Piedmont region east of the Blue Ridge are a few detached chains and isolated knobs.

The principal streams of the mountain region rise in the Blue Ridge, and these flowing westward break through the more elevated western barrier in deep chasms, the French Broad, the North Toe, and the Pigeon, all flowing into the Tennessee; and the Tuckasegee, into the Little Tennessee; while those on the other side of the ridge flowing eastward are the Yadkin, emptying into the Pee Dee River, and the Catawba, separated from the Yadkin by the Brushy Mountains and flowing first easterly and then southerly through the Piedmont region into the Atlantic.

The mountains are for the most part covered with timber up to their very summits, even Mt. Mitchell having considerable forest growth at the highest point; but there are a few peaks termed "Balds" with elevations of 5,000 feet or more whose rounded knobs are almost bare of timber.

General Temperature and Rainfall Conditions in Region as Affected by Elevation.—The modifying effect of elevation on the general meteorological conditions of the region is two-fold:—a reduction in temperature and an increase in rainfall. The isotherms as they approach from the eastern lowlands curve southward rapidly and, after crossing the mountains more or less irregularly at right angles, bend sharply northward; while the rainfall is much greater in the mountain region than at the lower levels, and is greatest over the more elevated sections, especially those on the side of the mountains facing the rain-bearing winds.

Taking temperature conditions in the sections to the east of the mountains as a basis, there is normally, because of the difference in

latitude, about 2° difference in the mean annual temperature between the northern and southern limits of this mountain region. In the lower levels the isotherm of 59° runs somewhat south of the Virginia-North Carolina border, while that of 61° is approximately in line with the Georgia-North Carolina boundary. Temperature data for the summits of the highest mountains are not available, but the means deduced from the observations at places having altitudes up to 4,000 feet are sufficient to show strikingly the effect of elevation upon temperature. The lowest computed annual mean for a considerable period in the mountain region is 49°, observed at Blowing Rock and Highlands, both about 3,600 feet above sea level, one place being in the extreme northwestern portion and the other in the extreme south-western portion of the state. Because of the difference in latitude, Blowing Rock should normally average 2° colder than Highlands, but this variation is not apparent in the observations because of difference in topography, the station at the latter place being located in a well marked frost pocket, where the night temperature averages uniformly low. This mean annual temperature of 49° is approximately the mean of the Weather Bureau station at Albany, N. Y., where the thermometer shelter stands about 100 feet above sea level.

The rainfall in the Carolina mountain region varies considerably and it is generally much heavier than on the Atlantic Plain. The largest amounts occur along the main Blue Ridge, especially on its southern and eastern sides, as the principal rain-bearing winds in that section are from east to south. The southerly winds carry the moisture-laden air from the Gulf of Mexico, and naturally the greatest rainfall is recorded at the stations farthest to the south where these southerly winds, moving northward, are pushed upward over the slopes, the cooling of the air resulting in condensation, often excessive. During a 4-year period, 1913-1916 inclusive, the gage at Highlands registered an average annual precipitation of 97.88 inches, the total in 1915 being 111.21 inches, and in 1916, 105.10 inches, two extremely wet years. In the same period the cooperative station at Rock House, formerly known as Horse Cove, about six miles southeast of Highlands, recorded an average rainfall of 94.62 inches. These figures are considerably above the average for a long period of years, which are respectively 80 and 82 inches, but in any case this spot in the mountain region close to the North Carolina-Georgia boundary is the wettest place in the United States, except the extreme north Pacific coast.

The rainfall over the Great Smokies is much less than along the Blue Ridge, because the southerly and easterly rain-bearing winds are shut off, or at least their moisture is largely condensed over the Blue Ridge before reaching the Smokies. Moreover, the rainfall on

the plateau inclosed by these two mountain ranges is very much less than on the surrounding mountains, obviously because of the condensation of a large portion of the moisture at the higher levels before the winds reach the plateau. Asheville, in the valley of the French Broad River, and walled in by mountains, registers an average annual rainfall of only 39 inches.

Scheme of Work and Distribution of Stations.—Although the special research was inaugurated in 1912, it was not until the first part of 1913 that all the stations selected were in full operation. The observations thereafter continued until the close of 1916. Stations were installed at 16 places in the mountain region, Bryson being the most westerly, Mt. Airy close to the Virginia border, the most northerly and easterly, and Highlands and Tryon, close to the Georgia and South Carolina borders, respectively, the most southerly. At these 16 places there was a total of 66 stations, varying at each place from 3 to 5 in number. The most elevated place is Highlands, with stations ranging in altitude from 3,350 feet to 4,075 feet, and the lowest is Tryon, its base station having an altitude of only 950 feet. Six of the slopes have differences in elevation between base and summit of 1,000 feet or more, the longest slope, 1,760 feet, being at Ellijay. Some of the slopes are steep, and others are gentle, irregular, and broken up into coves and frost pockets. Some are heavily timbered, while others are comparatively free from forest growth, just as certain of the individual stations are surrounded by dense vegetation while others are more or less bare.

At one place, Asheville, the stations are located above a valley floor on two facing slopes, northerly and southerly, while at two other places the stations are on slopes leading down from different sides of knobs. Nearly all the short slopes lead up to isolated knobs. Some of the valleys at the base of the slopes are narrow and confined, and others are comparatively broad; again, some base stations are located on broad benches. A wide range of conditions has thus been afforded for investigation.

The places were fairly well distributed, all being located in the main portion of the mountain district with the exception of Wilkesboro and Mount Airy, which lie in the foothills to the east. Two places, Blowing Rock and Altapass, are on the main Blue Ridge. There was no definite uniformity observed in determining the positions of the stations on the individual slopes, the exact locations in some cases being dependent upon conditions beyond the control of the investigator, the purpose being to place at least one or two stations in each group within an orchard when one was available.

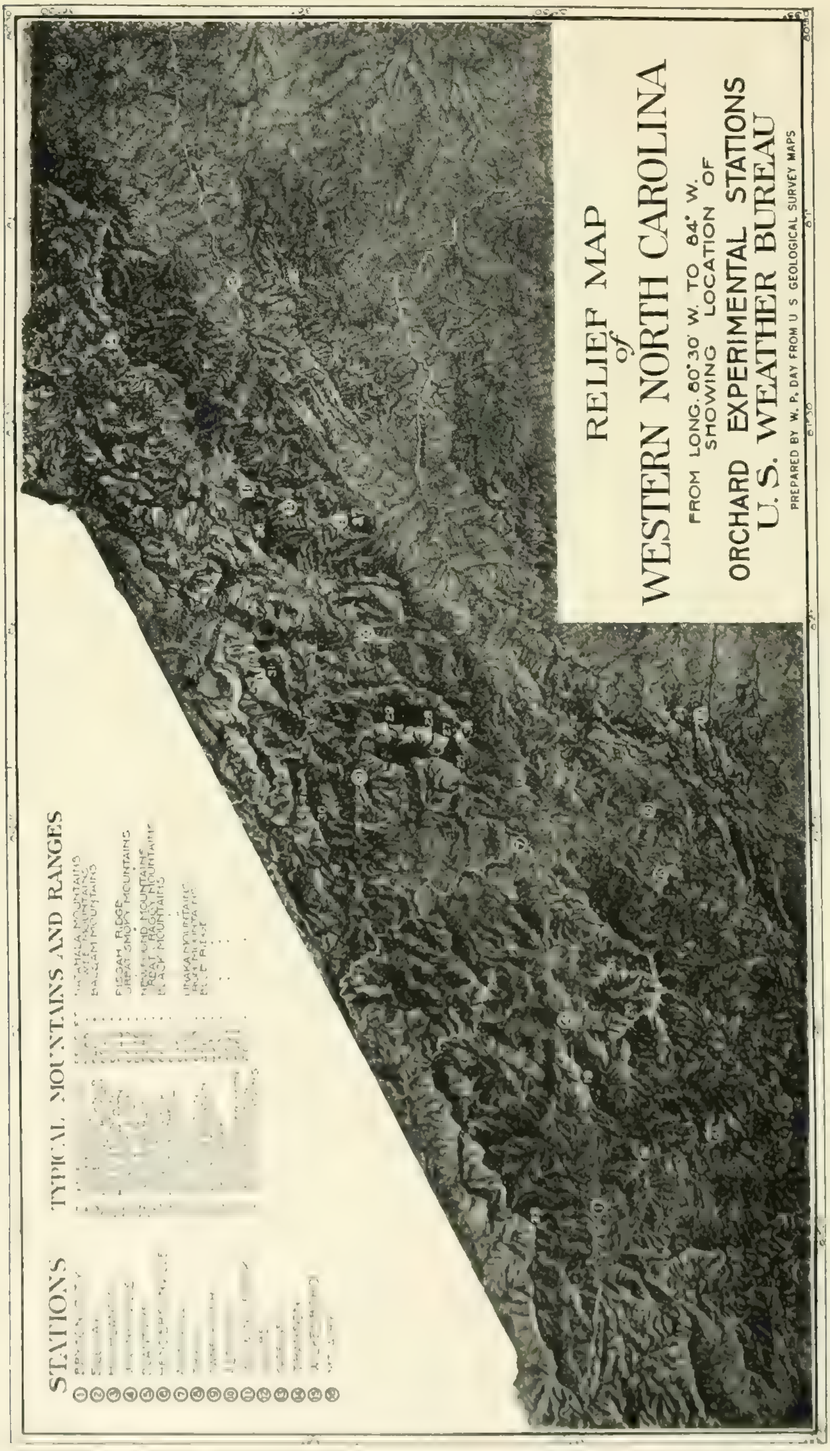

Fig. 1. Relief map showing location of stations.

Minimum Temperature and Causes of Inversion.—During the research a great variety of conditions was studied, including practically all meteorological factors,—maximum temperature and minimum temperature, relative and absolute humidity, rainfall, wind direction and velocity, cloudiness, sunshine, etc. However, in this brief paper the discussion will be confined to that of minimum temperature during both inversion and reversion conditions and its bearing upon the thermal belts and verdant zones.

In the mountain region there is frequently at night a complete reversal of average conditions, so far as minima are concerned. There, after the heat of the day, the entire valley is filled with a sea of comparatively warm air, but as night approaches and the loss of heat is greater than that received from the departing sun, the temperature falls steadily, the change being especially noticeable on the valley floors and the lower levels of the slopes close by where the sunshine is shut off early. On the floor of the valley, the surface air in contact with the soil and vegetal cover rapidly cools and remains stagnant, while the free air above is still warm. Moreover, the surface air in contact with the soil and vegetal cover on the slopes also gradually cools and, naturally, becomes cooler than the free air of the valley at the same levels. As differences in density develop, a convective circulation is established practically horizontally between this free air and the surface air of the slope, the latter as it cools draining slowly down and out over the valley. The free air, itself, loses its heat only slowly by radiation, and at the higher levels it naturally maintains a much higher temperature than the air below which has been cooled by contact with the slopes and valley floor. In this exchange between the warm free air of the valley and the surface air, the air over the slope is prevented from falling to as low a point as it otherwise would, and thus its temperature is higher than at the base. The degree of difference varies and is chiefly dependent upon the amount of free air available for interchange and the opportunities for radiation.

The observations in this region show remarkable temperature variations. The tendency toward inversion is so strong that this condition was observed four times as frequently as the supposed normal distribution of temperature or that of reversion. Moreover, at all places without exception the minimum temperature for the 4-year period, including all kinds of weather, averaged lowest on the valley floor. At Ellijay, where the slope has a vertical height of 1,760 feet above the base, the average minimum at the summit was 3.3° higher than on the valley floor, although, if the average lapse were maintained, the difference would be in the other direction and amount to approximately 6°. On individual nights, on this slope, and even at

the summit, the minimum was often 15° to 20° higher than at the base.

Generally speaking, throughout the mountain region inversions of 20° were frequently noted. The greatest inversion during the entire

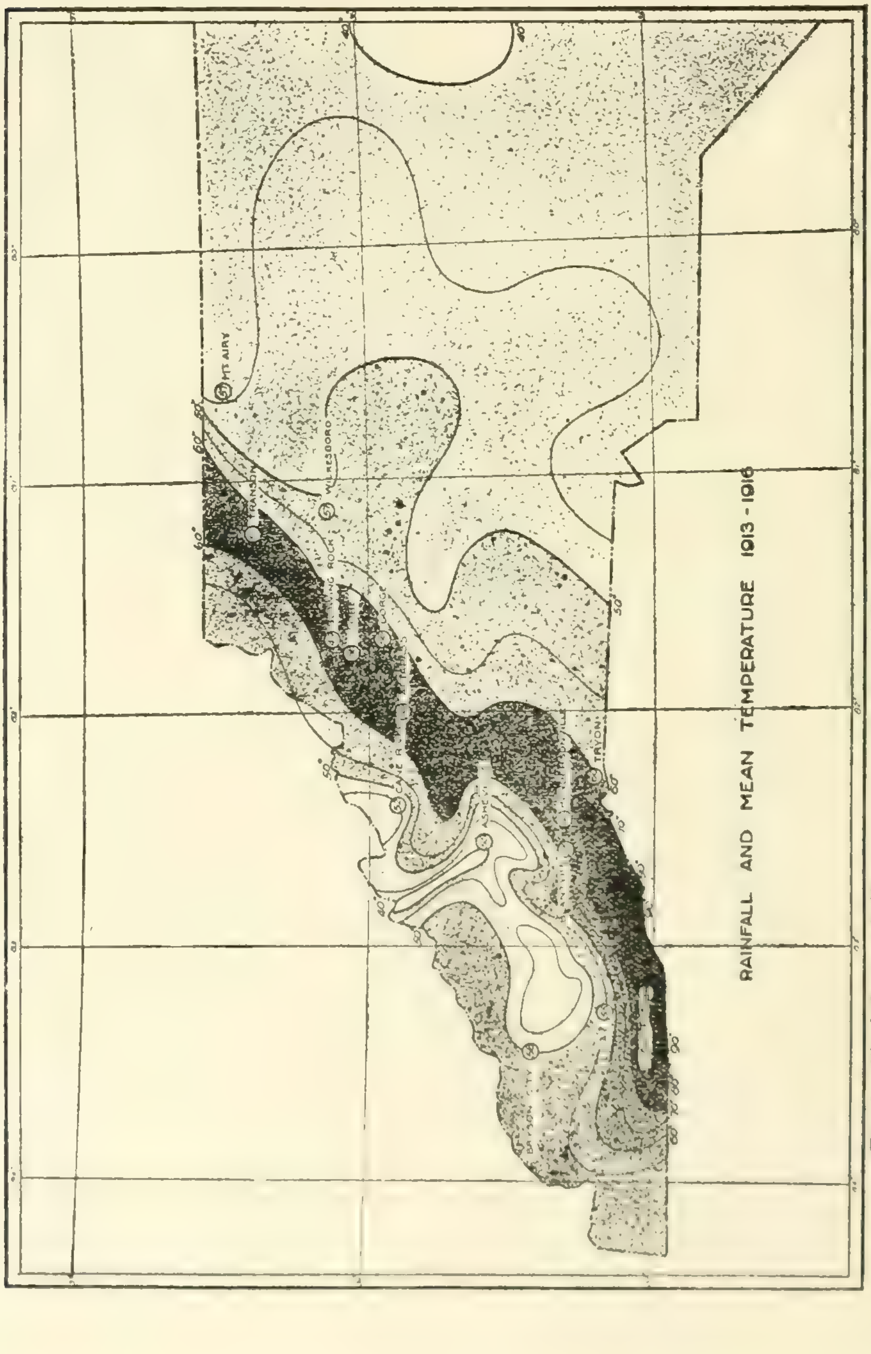

FIG. 2. Shaded areas indicate average annual rainfall and figures in circles the mean temperature.

research was observed on Brown Mountain, November 13, 1913, when the temperature at the summit registered 31° higher than at the base, more than 1,000 feet below.

Inversions have been supposed to be confined practically to anti-cyclonic conditions—high pressure and clear weather—which may be called the Ideal type. But inversions are also noted in the Carolina mountain region under cyclonic conditions, when as a storm approaches, the temperature rises much more rapidly at the summit than at the base, warm winds at the lower levels being shut off by obstructing mountains, and the cold air in pockets, coves and valleys being at the same time retained. There is even another type between the Anti-Cyclonic and the Cyclonic that might properly be called the Intermediate or Recovery type, although the term "weak-cyclonic" might answer. In this type the temperature is observed to be falling at the base and actually rising at the higher levels.

The highest minimum during inversion conditions was found at varying distances above the valley floors, depending upon the configuration of the surrounding country and the length of the slope. At Ellijay, the longest individual slope, 1,760 feet, the center of the thermal belt was usually at a point about 1,200 or 1,300 feet above the floor, while on all short slopes, less than 1,000 feet and leading up to knobs, the highest minima were observed on the knobs themselves during inversion weather.

THE INFLUENCE OF TOPOGRAPHY ON INVERSION.—The minimum is always low, or comparatively low, at points where there is little, if any, warm free air available for interchange. While this condition is most pronounced on a valley floor, it is also quite evident in a sheltered cove, even though located on a slope. On gradual slopes the minima are lower for the same reason than on steep slopes, a given area on the latter having a much larger amount of free warm air facing it, and at the same time not being so freely exposed to the sky as to suffer the same loss through radiation as the gentle slope. Again, when a slope has opposing mountains close by, thus reducing the amount of air available for interchange, the minima are even lower, though these mountains raise the sky line and thereby tend to reduce the loss of heat through radiation. This is especially noticeable in the lower levels of the gradual slope of Brown Mountain with low hills close by, where a station 250 feet above the base averages almost as cold as that on the valley floor.

Although the summit of a mountain is usually situated ideally for radiation purposes, with a free exposure in all directions, nevertheless, during inversion conditions the highest minimum is noted at the very summit, except when either its surrounding mass is great or

its vertical height is great, a knob partaking largely of the temperature of the free air.

The mass in the region of the summit is a most important factor. Where the mass is great, a large number of radiating surfaces are present which serve to reduce the temperature to a greater degree than if the summit were a mere knob, and in thus lowering the temperature in the vicinity of the summit, the center of the thermal belt is also lowered.

The center of the thermal belt is lowest, then, on a mountain slope where there is no opposing slope nearby and where the mass above in the region of the summit is great. The slope at Tryon is a typical example of this condition, where the highest minimum is usually found at an altitude of less than 500 feet above the valley floor, there often being differences of 15° to 20° between these points separated by only a few hundred feet.

On the other hand, the center of the thermal belt on a slope is high when the opposing slope culminates in a knob so that there is no considerable mass near the summit; and this is so whether there are opposing slopes or not.

When opposing slopes are present in the lower levels and there is a great mass above near the summit, the thermal belt is relatively narrow, as both these conditions tend toward lower night temperatures. Such a slope, as a whole, is cold. If, on the other hand, the slope is steep and there are no opposing slopes and no great mass near the summit, the entire side of the mountain is relatively warm during night inversions, here being present all the conditions that favor high minima.

The temperature, ordinarily, on a night of inversion, of course, falls along the entire slope as well as on the valley floor, but with increasing elevation it falls less and less, and the center of the belt rises steadily from nightfall to dawn.

Influence of Mountain Breeze.—The minima in the valleys are sometimes affected by the mountain breeze, but the observations show that this wind does not develop except where the mass of the mountain around the summit is great. Breezes do not blow down the sides of a mountain from a mere knob, but where the mass is great, as at Altapass on the main Blue Ridge, or at Tryon, the breeze is frequently observed. The mass being freely exposed with its great surface, like an elevated plateau, becomes covered at night with a blanket of cool air and, if the prevailing wind is favorable, after a time this cold air moves down the side of the mountain in a water-like flow, being mechanically warmed in its descent but, nevertheless, serving to lower the temperature, at least for a time, on the slope, although raising it in the valley below where the temperature has already fallen to a

low point. If the wind generally is blowing from an opposite direction, the mountain breeze does not develop, even though other conditions are prevalent. Of all the places used in the research, Tryon afforded the best examples of the effect of the mountain breeze. The observing stations at that place were located on Warrior Mountain, overlooking the village of Tryon, and close to the summit was the Saluda Plateau. When the air at night became unusually cool over the higher levels, it was observed to flow down the gorge of the Pacolet River and continue on through the valley, the thermograph traces on the valley floor showing unusual fluctuations.

Seasonal Fluctuation of Inversion Conditions.—Inversions are most frequent during the months of May and November when the weather conditions are usually settled in the mountain region, long periods of fair weather then prevailing. They are somewhat more pronounced in the latter month because of the greater length of the night, the thermal belt rising as the length of night increases.

Inversions are almost as frequent during the summer months, but their range is small. In the winter months, when they are much less frequent, the range is great and the type during that period is usually Intermediate or Cyclonic, under the influence of rapid storm movement.

Weather Conditions Affecting Inversion.—During a period of fair weather the amount of inversion is observed to increase steadily up to about the fifth night because air over the valley enclosed by the mountains becomes steadily warmer during the day, so that it has a larger and larger amount of warm air available for interchange with the surface temperature on the adjoining slopes. The time of maximum inversion sometimes occurs later than the fifth day, but finally the peak is reached, because increasing vapor and impurities in the form of dust and smoke, interfere with radiation.

The observations show that the amount of inversion depends decidedly upon both relative and absolute humidity. When there is considerable water vapor in the atmosphere the amount of inversion is small, and when the air is dry the range is correspondingly large. A humid period is always characterized by a small average daily range in temperature along the entire slope, the variation being slight in the day as well as in the night. The vapor pressure controls the degree of inversion in that the loss of heat by radiation through moist air is small, while through dry air it is large.

Places of Highest and Lowest Minimum Temperature.—The place of actual highest minimum in the mountain region largely depends upon elevation above sea level, because the lower the altitude the warmer the free air becomes in the daytime under the influence

of the sun's heat. So we find in the Carolina mountain region among the places employed in this research the highest average minimum on the slope at Tryon at an elevation of 1,350 feet above sea level and about 400 feet above the valley floor.

On the other hand, the lowest average minimum is found at a station at Highlands in a cove or frost pocket at an elevation of approximately 3,600 feet above sea level. However, in comparison with its altitude, this does not have the lowest average minimum for the entire region, as that is found at Blantyre on the valley floor of the French Broad River. The valley there is of considerable width, the grade is very slight, and towering mountains are in the distance, although no high peaks are close by. The bottom lands are marshy with dense vegetation, thus affording a vast area of radiating surface, with no opportunity for horizontal interchange with the warm free air above.

While the minimum averaged the lowest at the base, or valley floor station at all places employed in this research, occasionally, of course, the temperature at night was lower at the summit during "reversion" conditions. This was especially pronounced with strong west to northwest winds, bringing in cold waves. During such conditions the lowest minima at two of the places, Tryon and Altapass, occurred at the summit where the mass is great, but the lowest absolute minima for the entire region, —7° at Highlands and —6° at Blantyre, were observed at base stations under the anti-cyclonic type of inversion.

Damaging Effect of Changeable Temperature and Shortness of Season.—Fruit growing in the North Carolina mountain region, in spite of the thermal conditions referred to, is more or less hazardous. This is mainly due to the protracted periods of warm weather which often prevail during the wintertime, or early spring, swelling the buds and even forcing them open, only to be followed by disastrous freezes. The injury from this cause is seldom marked in the lowest levels, but is more serious at altitudes of 2,000 feet and above. In both the years 1913 and 1916, there were protracted warm spells in January followed by severe cold in February, and the buds were seriously damaged. Moreover, in the springs of these years additional freezes occurred after prolonged warm spells at the upper and middle levels; and, as a consequence, the fruit crop of the year was poor over the larger part of the area. Probably in no fruit growing section of the country is this phenomenon more frequently observed than in the North Carolina mountain region.

Again, in the higher levels, especially at places having an altitude of more than 3,000 feet, the season is comparatively short, there normally being freezes late in the spring and early in the autumn. At these places, at least, except on slopes, the growing season is usually so short that the fruit does not fully mature.

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RAINFALL OF THE GREAT PLAINS IN RELATION TO CULTIVATION*

J. WARREN SMITH

The land in the Great Plains States is easily cultivated and is naturally very fertile. Wherever sufficient moisture is available, either from rainfall or by irrigation, large crops are possible.

In eastern Texas, Oklahoma, and Kansas, and in southeastern Nebraska, the average annual rainfall is over 30 inches, and it is so well distributed that serious droughts are not of frequent occurrence.

In eastern New Mexico, Colorado, and Wyoming, extreme western Texas, Oklahoma and Kansas, western Nebraska and South Dakota, central and western North Dakota, and eastern Montana, the average annual rainfall is between 10 and 20 inches and droughts are frequent. In the years of light rainfall, or poor distribution there is not sufficient moisture for crops unless irrigation is possible. Even in the region where the annual rainfall averages between 20 and 25 inches, crops suffer in the years of light or poorly distributed rainfall. This is particularly true in the southern portion of the Great Plains where the summer temperature is high and evaporation is, consequently, greater than in the northern part. The 20-inch average annual rainfall line follows roughly the 100th meridian of longitude, being considerably west of it in Texas and Oklahoma, slightly west in Kansas and Nebraska, slightly east in South Dakota, and considerably east in North Dakota, as is shown in figure 1.

As a well-distributed rainfall of about 20 inches each year is necessary for crops, unless irrigated, it follows that the western Great Plains form a rather critical region for growing general farm crops. Even when the so-called dry-farming practice is resorted to, crop failures are not unknown.

Disregarding the arguments which might be presented to show that the effect of cultivation in the semiarid region must be negligible in causing the variation in temperature and humidity necessary to produce an increase in the amount of rainfall, we have turned our attention to ascertaining whether there has, or has not, been an increase in the precipitation over the Great Plains. All available rainfall records in that district were collected, tabulated, and charted in the accompanying graphs:

Figure 2 (A) shows curves of the annual rainfall, and the successive and progressive 5-year averages of the annual rainfall from

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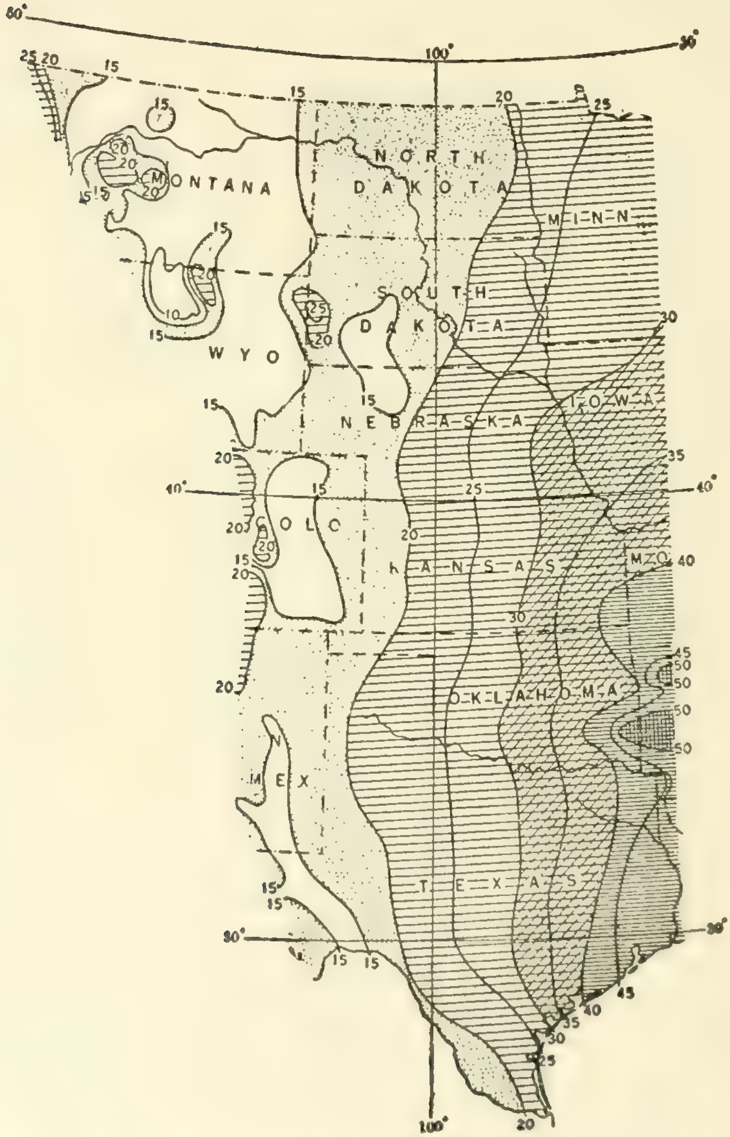

FIG. 1. Map showing the average annual precipitation in that part of the United States lying between the 93d and the 113th parallels of longitude. (From advance folio, Atlas of Amer. Agric.)

1867 to 1917, inclusive, for North Dakota, South Dakota, western Minnesota, and central and eastern Montana. Care was taken in this, as well as in the data for the other curves, to keep the stations well balanced between the wetter eastern and drier western parts of the districts.

The curves in A show a rise in the rainfall amounts from the early to the late seventies, followed by a rather sharp decrease to about 1889-90, and then a uniform increase until 1905 and 1906, and after that a moderate decrease.

The average annual rainfall for the first 25 years of this period is 19.6 inches and for the last 25 years 19.4 inches. The average precipitation for each 10 years, beginning with 1868, is shown in Table 1.

Table 1.—Precipitation for each 10 years from 1868 to 1917, inclusive, in the northern Great Plains.

Period	Precipitation (Inches)
1868–1877	19.8
1878–1887	20.4
1888–1897	18.0
1898–1907	19.5
1908–1917	19.1

Diagram B gives similar curves for the same period for Nebraska, central and western Kansas, eastern Colorado, and southeastern Wyoming. This indicates a wider variation in the annual rainfall than in the northern States, but the same two crests in the curve. One striking difference between them, however, is that, while in A the first crest was centered in 1877 to 1879, in B it was not reached until about 6 years later. As the second crest comes at about the same time in the two areas, the time between the two crests is 29 years in the northern area and only about 23 years in the central.

The average precipitation for the first 25 years of the period in the Central Great Plains was 18.4 inches, and in the second 18.7 inches. The average for each 10 years is given in Table 2.

Table 2.—Precipitation for each ten years from 1868 to 1917 inclusive in the central Great Plains.

Period	Precipitation (Inches)
1868–1877	16.3
1878–1887	20.4
1888–1897	17.6
1898–1907	20.2
1908–1917	18.2

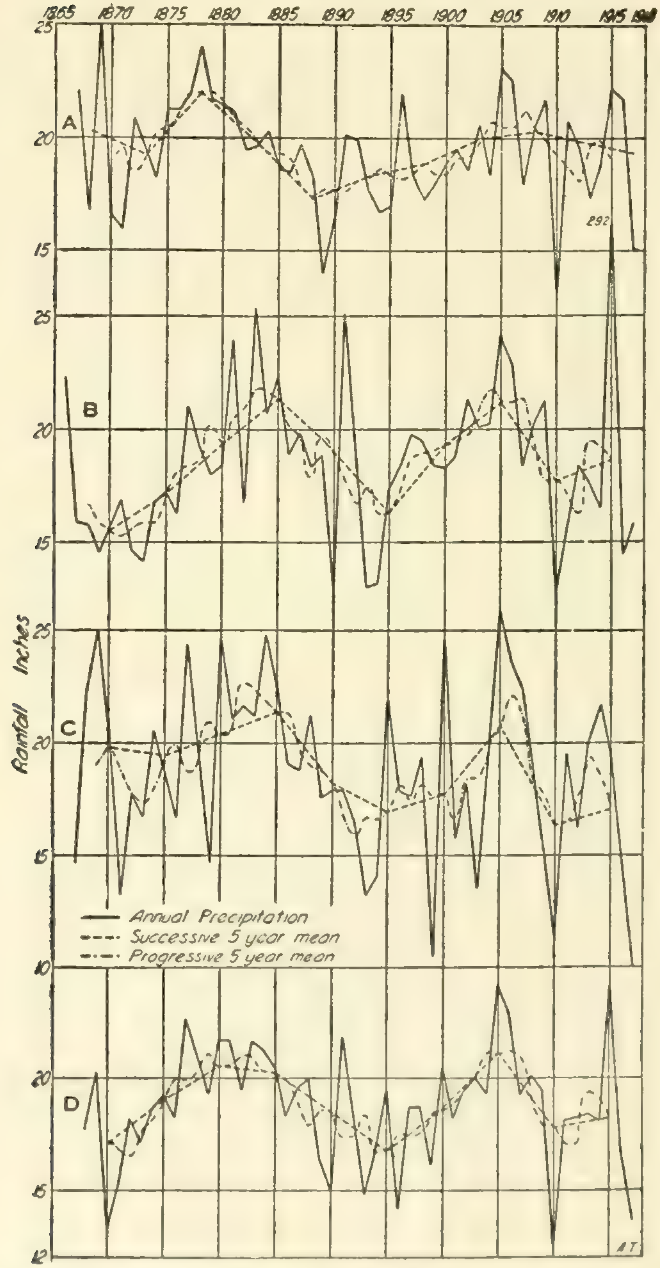

FIG. 2. Curves showing the average annual precipitation in (A) The Dakotas, western Minnesota, central and eastern Montana and northeastern Wyoming, 43 stations; (B) Nebraska, central and western Kansas, eastern Colorado, and southeastern Wyoming, 38 stations; (C) western Oklahoma and Texas, and central and eastern New Mexico, 40 stations; (D) average of the above, 121 stations.

In graph C there are similar curves for the southern Great Plains States, including western Oklahoma and Texas and eastern New Mexico. The first crest in this 50-year curve is at about the same time as in the central division, while the middle depression is slightly later than in either of the others.

The average annual rainfall for the 25 years from 1868 to 1892, inclusive, was 19.8 inches; for the next 25 years only 17.8 inches. The average for each 10 years is shown in Table 3.

Table 3.—Precipitation for each 10 years from 1868 to 1917, inclusive, and for the 12 years from 1852 to 1862 and 1867 in the southern Great Plains.

Period	Precipitation (Inches)
1852–1862 and 1867 (12 years)	18.8
1868–1877	19.6
1878–1887	20.8
1888–1897	17.5
1898–1907	19.3
1908–1917	16.7

In graph D the data, from which graphs A, B and C were prepared, were averaged so that this shows the annual and progressive and successive 5-year mean precipitation for the whole western Great Plains region.

This indicates two well-defined crests in rainfall about 25 years apart, with the low part of the curves at the beginning, middle, and end of the period of 50 years.

The average precipitation for the 25 years from 1868 to 1892, inclusive, was 19.2 inches, and from 1893 to 1917, inclusive, 18.4 inches. The average for each 10 years is shown in Table 4.

Table 4.—Precipitation for each 10 years from 1868 to 1917, inclusive over the western Great Plains.

Period	Precipitation (Inches)
1868–1877	18.1
1878–1887	20.4
1888–1897	17.5
1898–1907	19.9
1908–1917	18.4

There has been a decided increase in the area under cultivation in the Great Plains States during the past 50 years as brought out by figures in Table 5.

If increasing the area under cultivation in any district increased the precipitation, we should expect a steady rise in the annual rainfall amount over the region covered by this study. Instead of finding a regular increase, the graphs in Figure 2 make plain that there are

well-defined but comparatively short periods of increasing and decreasing rainfall, but which can not be due to cultivation. The crop area is being extended into the drier region because of crop adaptation and better farming methods. Moisture is conserved that formerly ran off, dry-farming methods are being adopted, and crops better adapted to the region are being planted.

An interesting fact in connection with the precipitation records is that dry years occasionally occur during a wet period or wet years in a dry period. This is brought out by the light rainfall in 1882 in graph B, and the very heavy rainfall in 1915 in graph D.

Table 5.—Acreage of certain grain crops in the Great Plains States.

Crop and State	Year			
	1867	1882	1892	1917
	Acres	Acres	Acres	Acres
Barley:				
Kansas	224	20,882	13,901	750,000
Nebraska	222	156,000	90,223	213,000
The Dakotas	...	28,273	321,693	2,845,000
Montana	...	1,852	5,032	90,000
Corn:				
Kansas	211,373	4,280,430	5,952,057	9,156,000
Nebraska	64,583	2,364,120	5,572,523	9,240,000
The Dakotas	...	186,247	811,526	3,940,000
Montana	...	492	1,080	81,000
Oats:				
Kansas	6,555	472,619	1,547,175	2,284,000
Nebraska	11,479	400,119	1,615,393	3,038,000
The Dakotas	...	140,000	1,174,449	4,500,000
Montana	...	28,000	66,323	680,000
Wheat:				
Kansas	89,285	1,573,000	4,070,724	3,737,000
Nebraska	9,917	1,657,000	1,253,564	997,000
The Dakotas	...	720,000	5,410,077	10,716,000
Montana	...	42,812	41,761	1,727,000

The opinion is expressed by some students of weather data that dry and wet years come in groups of two or three each, but this belief is not substantiated by these charts. In other words it is not possible to predict what the total precipitation for any year will be from past records. A wet year may be followed by another wet one or by a very dry year or vice versa. For example the dry year in 1890, in graph B, was followed by one of the wettest in the whole period, while the dry year of 1913 was followed by one equally dry.

In graph D it will be seen that the wet year of 1877 was followed by one nearly as wet; that of 1891 by a rainfall not far from the normal; that of 1905 by another wet year, and 1915, by one with considerably less precipitation than the normal.

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FEATURES OF GLACIAL ORIGIN IN MONTANA AND IDAHO

A Shaler Memorial Study

W. M. DAVIS

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INTRODUCTION: *The Transcontinental Excursion of* 1912.—When the Transcontinental Excursion of 1912, organized by the American Geographical Society in celebration of its sixtieth anniversary, was passing northwestward through the Rocky Mountains of Montana in September of that year, several members of the party were imprest, as we ran down the valley of Flathead River to its continuation in that of Clark Fork, one of the larger valleys of the Columbia system, with the change from the normally dissected valley sides of the upper branches to the scourd and oversteepend valley sides, increasingly developd down the main stream, as if due to erosion by a glacier that had advanced southeastward up the valley. The change began with the laying bare of soil-stript rocks to a small height above the valley floor without noticeable alteration of hillside form; then came the scouring and plucking of ragged ledges in the basal slopes to a height of several hundred feet, whereby the concave descent of the normal spur-ends was steepend to a convex descent; a few miles farther on the changes became more pronounced in the deep channeling and partial truncation of the spurs; this continued with steadily increasing strength, until after twenty or thirty miles the spurs were strongly truncated, and so continued farther toward Lake Pend Oreille in northern Idaho. The oversteepend

valley walls, surmounted by rounded summits with normally graded slopes and indented at the top by hanging valleys of normal form, descended to the broadly aggraded valley floor in bold and often precipitous cliffs sometimes a good thousand feet in height. What we had at first suspected, we were then prepared to assert with confidence:—a mature valley of normal form, deeply incised in a mountainous highland, gradually becomes an overdeepend glacial trough, and the glacier which excavated the trough, must have advanced up stream southeastward. Mr. R. W. Brock, then director of the Geological Survey of Canada, who was a member of our party, suggested that the invading ice was a branch of a Canadian glacier, which had crost the international boundary by an open pass on its way southward from the higher mountains of the north. It later appeard that the branch glacier, which had thus come to invade the valley of Clark fork against the flow of its river, had been recognized as the barrier of a temporary proglacial lake—Lake Missoula—first described by Pardee in 1910, the numerous and faint, high-level shorelines of which we had seen, before reaching the scourd part of the valley, on certain treeless mountain slopes in the branch valleys of Upper Clark fork in Montana. It then came to mind that, if this were true, the branch glacier that ascended the main valley of Clark fork must, towards its southeastern extremity where its scouring reachd but a few hundred feet up on the valley sides, have rested on the bottom of the valley under a thousand feet or more of lake water; for the highest shorelines, which could have been made only at the time of the greatest glacial advance, lie at some such height above the level at which the scourd spur-ends were first seen. If this should prove to be the case, it would afford a striking confirmation, and indeed an extension of Gilbert's theory that glaciers which scour out fiord troughs rest so firmly on the trough-bottom that no water can enter underneath to buoy them up, and that they therefore press upon the trough bottom with their entire weight, and continue to be effective eroding agents hundreds of feet below sea level.

A Visit to Clark Fork in 1913.—In order to test this point I revisited the valley of Clark fork in August, 1913; a grant for this purpose having been allowd me from the Shaler Memorial Fund of Harvard University, for which I hereby express my grateful appreciation. The reconnaissance of 1913 was not limited to the valley of Clark fork, but extended into several other valleys of Idaho and Montana, and into Canada along the deep intermont depression occupied by Lake Kootenai, from which the great Canadian glacier came southward into the Pend Oreille region. Confirmation was thus found for Brock's general suggestion regarding the Canadian source of much

of the ice in the valleys south of the international boundary, a suggestion which has since been found to be antedated twenty years or more by the views of several other geologists. It was furthermore found that the highest shore lines of Lake Missoula stand from 1,000 to 1,700 feet above the base of the truncated spurs in Clark fork valley. Hence it appeard that the truncation of the spurs was the work of a deeply submerged glacier; and this glacier was then believd to be a long and narrow branch of the greater glacier which came from the long trough valley of Lake Kootenai.

The preparation of the present essay was delayed by my voyage across the Pacific on a Shaler Memorial study of coral reefs, which occupied most of 1914, and by work on observations then made after my return home. After the manuscript was completed in 1915 it was long held by the censors to whom it was submitted by the editor, according to the rules of our Association; and after it was returnd to me with the censors' comments, still further delays intervened for a time in connection with the Great War. Altho publication has been in this way long postponed, the description of the facts observd still holds good, and the discussion of the facts has been improved by seasoning, as will appear below. The belated and revised essay is therefore now offerd to the scientific public.

Modifications of First Conclusions.—Certain important modifications of my previous conclusions were urged by one of my censors. First, to the effect that the glacial erosion in the valley of Upper Clark fork, which I had attributed to the up-stream advance of a long and narrow distributary branch of the main Kootenai-Pend Oreille glacier, should be ascribed at least in part to glaciers of more local origin and less length. The reasons offered for this modification were on the one hand that my observations did not suffice to prove the continuity of a single glacier; and on the other hand that it was physically impossible for a long and narrow glacier to advance so far up a valley of somewhat irregular form. Second, to the effect that a glacier could not possibly remain submerged in an ice-bard lake and there continue its erosional work in the manner that I had been driven to suppose. These comments appear to me to have much weight; indeed I had previously found difficulty myself in accounting for so long an advance of a branch glacier up a comparativly narrow valley against gravity, and for its remaining submerged while it eroded the valley sides; but the possibility of independent sources for one or more local Clark fork glaciers had not occurd to me; and the submergence of the eroding glacier seemd a necessity because it was assumed to be synchronous with the submerging lake. After careful consideration, both of these chief modifications have proved to be

helpful, and they are therefore welcomed in the final revision to which the essay has been submitted. They are essentially incorporated in its present form. It may be remarkd in passing that the improvement of the essay thus gained is, in my opinion, a strong recommendation for the censor system adopted by our Association; and also that personal credit would gladly be given here for the improvement, had not the censor to whom it is due preferd to remain anonymous.

OUTLINE OF ESSAY. *Subdivision of the Region.*—The Rocky Mountain system in Montana and Idaho, between the Great plains on the east and the Columbia lava plateau on the west includes a number of ranges and plateau-like highlands of deformd crystalline and stratified rocks, which frequently show even skylines and thus strongly suggest that they represent a formerly worn-down mountain system, irregularly warpt and uplifted again in narrower or broader belts of less or greater altitude, the higher belts being now maturely dissected, while the lowest ones are more or less aggraded. A serviceable review of the physiographic history of the mountains has been prepared by J. L. Rich.[1] The larger features of relief thus produced generally trend about north and south, or northwest and southeast, and reach altitudes of 8,000, 9,000, or 10,000 feet. The higher mountains show abundant signs of strong sculpturing by local glaciers, and two of the largest intermont depressions—those of Flathead lake on the east and of Kootenai and Pend Oreille lakes on the west—bear the manifest records of strong erosion and of heavy deposition by broad south-moving glaciers from the Canadian mountains.

For our present purposes the mountainous area of northwestern Montana and northern Idaho may be divided as in Fig. 1, following the nomenclature of Daly[2] and other writers, into three chief members, divided by the two intermont depressions just mentiond. These five large features all extend northward into Canada. The eastern member includes several ranges of the Rocky Mountains proper which next south of the international boundary rise in the sharpend Alpine peaks of Glacier National Park; their westernmost elements in our district are the Galton and Swan ranges. The middle mountainous member includes the southern extension of the Purcell range from Canada into the Cabinet and Flathead mountains of Montana; the mountains last named being separated from the Purcell range by the transverse valley of Kootenai river on its course from the eastern

[1] J. L. Rich, An Old Erosion Surface in Idaho; Is It Eocene? *Econ. Geol.*, XIII, 1918, pp. 120-136.

[2] R. A. Daly, The Nomenclature of the North American Cordillera, *Geog. Jour.*, XXVII, 1906, pp. 586-606.

to the western intermont depression. The westernmost member includes the Selkirk range of Canada and its dependencies in northern Idaho.

The Two Longitudinal Depressions.—The eastern one of the two long depressions is for the most part broadly aggraded with glacial deposits; it extends into Canada as the long and narrow Rocky Mountain trench in which the Columbia and the Kootenai rivers head against each other and flow in opposite directions, only to join each other far to the west after flowing thru irregular transverse valleys. The part of the eastern depression that lies in Montana has an extension of 110 miles south of the boundary, and a breadth of from 12

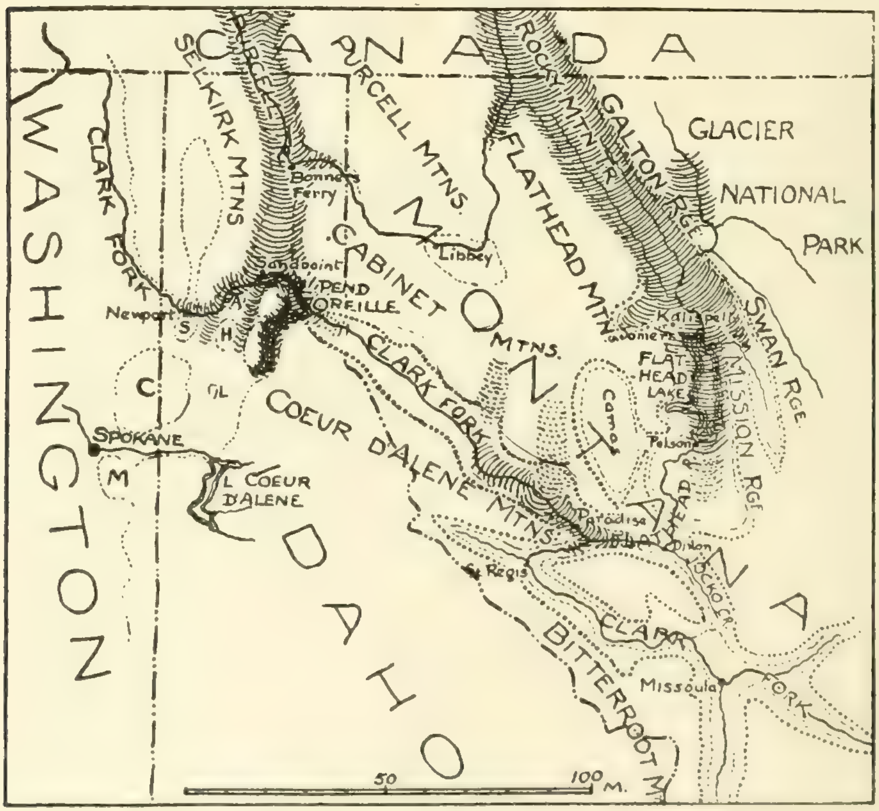

FIG. 1. Outline map of region.

to 30 miles; it will here be calld the Flathead trough, after the lake that it contains and the river that drains it southward; its southern part is divided by the Mission range of which I have given account elsewhere[3] into a narrower and shorter eastern branch, draind north-

[3] W. M. Davis, The Mission Range, Montana; Proc. Nat. Acad. Sci., 1915, pp. 626-8; also, *Geog. Rev.*, II, 1916, pp. 267-88.

ward by Swan river to Flathead lake, and a broader and longer western branch which is draind southward thru Flathead lake by Flathead river. Flathead lake, about 2,900 feet in altitude, 27 miles long north and south, by from six to fifteen miles wide east and west, with no authentic soundings that I could discover but reputed to be several hundred feet deep, occupies the northern half of the western branch, with the town of Somers at its northwestern angle, five miles west of Flathead river inlet, and the town of Polson at its southwestern curve near the outlet. Kalispell, the chief town of an agricultural district, lies on the broadly aggraded plain ten miles north of the lake.

Kootenai river, following the Rocky Mountain trench southeastward, turns southwestward just after crossing the international boundary, and thus for forty miles obliquely traverses the middle mountainous member, from which it escapes by turning a right angle into another oblique course of fifty miles to the western depression. This irregular transverse valley is taken, as above noted, to mark the southern limit of the Purcell range. The Great Northern railway, which traverses the eastern ranges by following valleys of the Flathead system south of Glacier National park, originally crost the Flathead depression southwestward, and then made its way thru the Flathead mountains by comparatively open valleys to the right-angle turn of Kootenai river at the southernmost point of the Purcell range; but now the Flathead depression is followd northwestward over an open valley-floor divide to the Kootenai river, and this river is then followd in all its irregular course thru the middle mountains to the western depression. The railway thus increases distance but saves grades.

The narrower western depression is known in Canada as the Purcell trench: a good part of it is occupied by Kootenai lake, 1,760 feet in altitude, 65 miles in length and two or three in width, with a reported depth of 800 feet; the southern end of the lake is twenty miles north of the international boundary. The depression branches irregularly at its southern end among various mountain masses in northern Idaho; the western branch is followed by the lower course of Clark fork after it flows out of Pend Oreille lake, the southwestern branch broadens and opens upon the Columbia lava plateau at Spokane; the long southeastern branch is the valley of Clark fork with which we are here especially concernd; the southern or central branch is occupied by Pend Oreille lake, 2,051 feet in altitude, 24 miles in length north and south, by two or three miles in width, with a sounding, reported as trustworthy, of 1,300 feet: the southern part of the depression will be here named after this lake. The town of Sandpoint at the northern end of the lake lies on the aggraded floor of the depression fifty miles south of the international boundary; the aggraded section

of the depression continues north to Kootenai lake. Kootenai river, after entering the depression from the east twenty miles south of the boundary, turns north-northwest along it to the lake of the same name; the town of Bonners Ferry lies at the river turn, which will be here named the Bonner elbow of the river. The parts of the two great depressions here chiefly referd to may be given the river-and-lake names, Kootenai-Flathead and Kootenai-Pend Oreille.

Flathead River and Clark Fork.—Flathead River, after leaving its lake, flows thru the broad western branch of the Flathead trough and then cuts thru a low range for a few miles to a well defined valley of varying width, trending in general from southeast to northwest and lying between the Cabinet and Flathead mountains on the north and the Coeur d'Alene and Bitterroot mountains on the south; here it receives Jocko creek from the southeast, and then bending square to the west-northwest—the village of Dixon lies at the bend—it joins Clark fork twenty miles farther on, at the second apex of a sharp backhanded turn or zigzag by which this river shifts from one northwestward course to another. Clark fork, formerly called Missoula river, is now justly known by the name given to it over a hundred years ago by one of its earliest explorers in honor of his companion. It brings down the drainage from a large mountainous area on the southeast, where one of its chief branches is the Bitterroot, coming from a fine valley on the south. Reinforced at its backhanded turn by the Flathead, it continues eighty miles northwestward along the extension of the well-defined Flathead valley of western Montana—the valley mentiond at the opening of this paper—thru the mountainous highlands to the northern end of Lake Pend Oreille in Idaho. Clark fork is followd by the Northern Pacific railway in a continuous down grade from its headwaters for 200 miles to the lake; but in order to save distance at the expense of grade, a short-cut has been made for passenger trains, from the junction of Bitterroot river, where the town of Missoula is situated, over Evaro pass, 3,971 feet, to the headwaters of Jocko creek and then down a section of Flathead river, joining the original line on the main river at its backhanded turn or zigzag. The railway division station of Paradise lies a mile below the junction. The village of St. Regis lies at the other apex of the zigzag river course.

Clark fork continues as the outlet of Pend Oreille lake, and thus flows thirty miles westward thru the isolated ranges of the westernmost mountain belt into the Columbia plateau of heavy lava flows, where they overlap the western flanks of the mountains, thus passing from Idaho to Washington. Here the river turns to an entrenchd northward course for fifty miles, and at the international

boundary joins the Columbia river which there comes southward from the Canadian valleys. The part of the river below Lake Pend Oreille will be here spoken of as Lower Clark fork; and the part above the lake as Upper Clark fork. The Great Northern railway turns southward from Bonners Ferry to Sandpoint at the north end of Pend Oreille lake, follows the lake outlet for 25 miles to the Idaho-Washington line, where the town of Newport is situated, and then runs southward forty miles to the city of Spokane. The Northern Pacific railway rounds the north end of the lake and takes a more direct course to the same city; the Rocky Mountain division of the Chicago, Milwaukee and St. Paul railroad, which parallels the Northern Pacific for many miles along the valley of Upper Clark fork, reaches Spokane by a more direct course from the St. Regis apex of the Clark-fork turn, over the mountains of the Coeur d'Alene mining district. The Oregon Railroad and Navigation Company's line reaches Spokane from the southeast, and the Canadian Pacific sends a branch line southwestward thru our district past the Bonner elbow of Kootenai river and the northern end of Pend Oreille lake, in order to reach the growing metropolis of the "Inland Empire."

Two Great Canadian Glaciers.—The traces of the two great Canadian glaciers, here to be called the Kootenai-Flathead and the Kootenai-Pend Oreille, are easily followd southward from Canada along the great intermont depressions into the Flathead and Pend Oreille troughs; the paths of tributary glaciers may be traced back into the higher mountains adjoining the great depression; the eastern depression is associated with the strong glacial features of Glacier National Park south of the international boundary. The traces of the eastern or Kootenai-Flathead glacier cover a greater breadth, east and west, and extend somewhat farther south than those of the western or Kootenai-Pend Oreille glacier. It is in connection with an outgoing branch or distributary of the latter glacier, the traces of which extend into the valley of Upper Clark fork where it may have had local reinforcement, that the sublacustrine glacial scouring in the vanisht Lake Missoula is considered in the latter part of this essay.

The southern limit of the broad Kootenai-Flathead glacier is markt by two great terminal moraines, one strong and fresh looking, the other farther south and of softer contours, in the southern part of the Flathead trough; inside (north) of the younger and more northern moraine, here to be called the Polson moraine after the town on its inner slope, lies the existing Flathead lake; to the older and more southern moraine the name of Mission will be given, after the long-established Mission of St. Ignatius, which lies a little farther southeast.

The southern extensions of the Kootenai-Pend Oreille glacier are traceable along its several distributary branches, separated by intermediate mountains, as will be described in a later section.

ITINERARY. *The Outward Journey.* The description of various features on later pages will follow the order of their physiographic relations, not that of their observation, which may be inferd from the following itinerary. Most localities here mentiond are indicated on Fig. 1. After leaving Cambridge on July 27, 1913, and making several stops on the way, I reached the Rocky Mountains and crosst the continental divide west of Helena, Montana, by the tunnel under Mullen pass (5,800′) on the Northern Pacific railway in the morning of August 2. Thus an upper valley of the Clark fork-Columbia drainage system was entered at its very head. That afternoon I left the train just below the junction of Flathead river with Clark fork at the railway division station of Paradise, where three days were given to local excursions on foot and by rail. On August 6, I went by train ninety miles northwestward down the valley of Upper Clark fork—stops being made at two stations on the way—to the northern end of Pend Oreille lake, around which the railway turns to a southwestward course of sixty miles to Spokane, on the eastern border of the Columbia lava plateau a few miles within the State of Washington. August 7 was spent in Spokane, and August 8 on Lake Coeur d'Alene in the mountains thirty miles east of Spokane; the nights of August 8, 9, and 10 were past most agreeably at Hayden lake, thirty miles east of Spokane and ten miles north of Coeur d'Alene, at the beautiful country seat of one of my students of thirty years ago. Automobile excursions on August 9 and 10 showd me many interesting features in connection with the extensiv outwashd gravel plain of the Pend Oreille glacier.

The Return Journey.—On the morning of August 13 the return journey from Spokane was begun by the Great Northern railway, northeastward to the Bonner elbow in the Kootenai-Pend Oreille trough, where Kootenai river enters it from the east and turns north to Canada again. The train ride was continued into the transverse valley of the Kootenai and back to Bonners Ferry in the afternoon. On the next day a roundabout excursion was made by the Canadian Pacific railway northeastward and westward to Kootenai lake in Canada, and back the day after to Bonners Ferry. August 15 was given to the broad valley of Kootenai river between Bonners Ferry and Kootenai lake. That night the eastward journey was continued by the Great Northern railway to Belton, the western entrance to Glacier National Park, and the next day was spent in the Park on

Lake McDonald. On August 18 a turn was made southwestward across the broad plain of Flathead trough to the town of Kalispell not far north of Flathead lake; that afternoon Mr. H. F. Smith, a Harvard student, took me on an interesting excursion to a lateral moraine of the great Kootenai-Flathead glacier near the north end of the Mission range; the night was spent at Somers at the northwest angle of Flathead lake. On August 19, a steamboat carried me 27 miles to Polson at the southern end of the lake, where an automobile was taken 35 miles farther south to Ravalli station of the Northern Pacific railway on Jocko creek. The next day I went by train a few miles farther up the valley to Arlee, where a cut was made for me with pick and shovel in one of the faint shorelines of Lake Missoula, and it was thus learnd that the faintness of the shorelines is largely due to their having been obscured by downhill wash or creep of detritus. Return to Polson was made by train and automobile the same afternoon. On August 21 the Polson moraine was examined on foot in the morning; steamboat and train carried me in the afternoon back to Kalispell, where excursions were made the next day to the steepend spur ends of the Swan range on the eastern side of the Flathead trough, and into the margin of the lower mountains on the western side of the trough. The return journey was resumed by the Great Northern railway on August 23, and continued from Duluth by steamer to Detroit. Cambridge was reached on September 3, 1913.

Some of the observations set forth in the following pages were made from the windows of running trains or the deck of a passing steamboat. Estimates of local relief are rough, and I fear in some cases far from accurate. Evidence of glacial sculpture was provided almost entirely by peculiarities of mountain-side form, occasionally by the presence of moraines and boulders, and only rarely by striated rock surfaces. Most of the sketches here reproduced are simplified diagrams rather than accurate pictures; their details are more or less fanciful, for it was impossible to make finished drawings on the spot. Members of the forest service in particular must find fault with them for the omission of many trees and groves; yet the hill and valley outlines may serve as a helpful supplement to verbal description.

Literature and Maps.—A number of articles that give information regarding the region visited are referred to in later paragraphs. Important among these are:—Daly's essay on the Nomenclature of the North American Cordillera,[4] Calkins' bulletin on a reconnoissance in northern Idaho and northwestern Montana,[5] Pardee's account of the

[4] R. A. Daly, The Nomenclature of the North American Cordillera, *Geog. Jour.*, XXVII, 1906, pp. 586-606.

[5] F. C. Calkins, Geological Reconnaissance in Northern Idaho and Northwestern Montana, *Bull.* 348, *U. S. Geol. Surv.*

Glacial Lake Missoula,[6] Elrod's account of the Flathead lake district,[7] and certain pages of the Guide-book of the Western United States, Part A, Northern Pacific Route.[8] During the discussion of my notes, I have had the advantage of conferring with Mr. R. W. Stone, of the United States Geological Survey, who contributed an account of Glacial Lake Missoula to the Princeton meeting of the Geological Society of America, January 1, 1914.

The larger part of the region visited on my excursion is not yet coverd by the topographic maps of the U. S. Geological Survey. The headwaters of Clark fork are included in the Ovando, Coopers Lake, Missoula, Bonner, Helena, Hamilton, Sapphire and Philipsburg quadrangles, all in Montana; some of the Flathead sources are shown on the Kintla Lakes and Chief Mountain quadrangles in Glacier National Park, also in Montana: Lakes Pend Oreille and Coeur d'Alene are mostly covered by the Sandpoint, Priest Lake, Rathdrum and Cataldo quadrangles, Idaho; and the Spokane district by the Spokane and Oaksdale quadrangles, Washington. The valley of Upper Clark fork, and the broad Flathead trough are not yet mapt. A rough map of the Flathead district, based on the surveys of the Land Office has been publishd, but is not now easily obtainable.

Order of Description.—The physiographic descriptions of the following pages will begin with an account of the Kootenai-Flathead depression south of the international boundary, where the records of a broad glacier of Canadian origin are relatively simple and manifest. An account of the Kootenai-Pend Oreille depression comes next, including the striking features of Kootenai lake north of the boundary, as well as the more complicated features of the several distributary arms to which this great depression leads. A number of detaild features associated with the extensiv gravel plain southwestward from these arms will then be briefly described. The features due to glacial erosion in Upper Clark fork valley follow next, and the shorelines of Lake Missoula, bard on the west by the Kootenai-Pend Oreille glacier, will be considerd in the closing pages.

The Kootenai-Flathead Depression. *Its Northern Extension.*—No account that I have found of the Canadian portion of this depression does justice to the great amount of glacial erosion which it records, if it be in that respect at all comparable with the Kootenai-Pend

[6] T. J. Pardee, The Glacial Lake Missoula, *Jour. Geol.* XVIII, 1910, pp. 376-86.

[7] M. F. Elrod, A Biological Reconnaissance in the Vicinity of Flathead Lake, *Bull. Univ. Montana*, Biol. Ser., 1902, pp. 91-182.

[8] M. R. Campbell and Others, Guidebook of the Western United States, Part A, The Northern Pacific Route, *Bull.* 611, *U. S. Geol. Surv.*

Oreille depression farther west. My own views of its northern portion are limited to two traverses on the Canadian Pacific railway, first in 1897, before I had learnd to recognize the larger forms of glacial sculpture, and again in 1909, when such forms had acquired a fuller meaning; but both traverses were rapid and the views allowd were incomplete. South of the international boundary the depression soon widens to a basin-like breadth in the district of Flathead lake, where its aggraded floor, standing at an altitude of nearly 3,000 feet, has a width of twenty or more miles.

Normally Eroded Valleys of the Swan Range.—The special interest of these ranges, the westernmost members of this part of the Rocky Mountains proper, in the present connection turns on the truncation of their western spurs. As the ranges are believd to be limited on the west by a fault, the movement on which separated the broad Rocky Mountain mass from the Flathead depression, the truncation of the spurs might at first thought be ascribed to faulting: but a closer examination of the case leads to the opinion that whatever fault scarp may have once existed here has been so maturely dissected into ravines and spurs that no trace of its face remains visible; and that the truncated spur ends are the result of lateral scouring by the great Kootenai-Flathead glacier. The truncation of the spurs is best seen on the Swan range for some ten or fifteen miles south of the deep notch where Flathead river, after gathering its branches from various longitudinal valleys within the mountains, makes its escape to the broadly aggraded plains of the depression-floor on the west. There the Great Northern railway also leaves the mountains, which it enterd by the singular pass at their eastern base, where the slow ascent for hundreds of miles across the Great Plains is suddenly exchanged for a rapid descent into a steep valley head of a Flathead branch. The truncated spurs at the western base of the mountains are seen to the south just before reaching Columbia Falls station on Flathead river, west of its deep notch.

The automobile trip that I made from Kalispell nearly to Flathead river notch and thence southward to the last of the truncated spurs persuaded me that their form is due to glacial erosion and not to faulting; for the truncation weakens southward, and about where it ends a broad belt of morainic hills departs from the mountain base and swings obliquely across the valley of Swan river, east of the Mission range. The higher slopes of the Swan range, as seen from the basin plain on the west, Figs. Nos. 2, 3, and 4, exhibit as a rule forms of mature normal dissection, with few, if any, indications of structural guidance in the determination of ridges or ravines. The crest is for the most part moderately sinuous, but in certain

stretches it is remarkably smooth, as if it there still retaind uplifted and unconsumed areas of the old mountain form,—perhaps deserving to be called a peneplain,—which characterizes so many of the highlands hereabouts. Where the retrogressiv encroachment of opposing interior and exterior valleys has resulted in producing notches in the crest line, they are not as yet deeply incised. Some of the valley heads are widend in cirque-like form, and continued downward in open troughs, apparently the results of feeble local glaciation; but the troughs are replaced by normal valleys toward the range base. The spurs, above the trough walls and trough sides, are altogether of normal form, down to the truncation of their lower ends. Some of the spurs seem to descend from advancing, high-level, promontory points of the apparently even highland surface that is indicated by the smoother parts of the crest line; other spurs head in summits that are isolated between notches. The spur ridge lines slope forward at angles of 20° or 30°. They present the variety of form usually seen

FIG. 2. Truncated spur ends, Swan Range, looking east.

in dissected scarps of fairly homogeneous rocks; for some are simply single spurs that descend between sub-parallel valleys from crest to base; some are tapering, dwindling spurs that lie between converging, confluent valleys, and therefore fail to reach the mountain base; and some lie between diverging valleys and broaden downward in a sprawling pattern, split into spurlets toward the base by short ravines. The consequent valleys and ravines vary appropriately to the variations of the spurs that remain between them. Some are single valleys of direct descent, enclosed by sub-parallel spurs from head to mouth; some converge from heads several miles apart to a single valley at the range base, being enclosed by sprawling spurs on either side and separated by dwindling spurs; some are merely short ravines that split the piedmont spurlets of large sprawling spurs. In short, the western face of the Flathead range presents the features characteristic of a maturely dissected fault scarp, such as I have described in certain stretches along the western face of the Wasatch range in Utah[9]; and it is because the Wasatch spurs are frequently truncated

[9] The Mountain Ranges of the Great Basin, *Bull. Mus. Comp. Zool.*, xlii, 1903, pp. 129-77; reprinted in Geographical Essays, Boston, 1909.

by terminal facets which have been with good reason regarded as residual parts of a great fault scarp that the question was raisd above as to the similar truncation of the Swan range spur ends; but the base of the Wasatch range has not been scourd longtitudinally by a great glacier.

Truncated Spur Ends of the Swan Range.—The terminal facets of the Swan range spurs were estimated to reach heights of 600 feet or more near Flathead river notch; but, as already noted, their height decreases southward, and the last one is not more than 100 or 200 feet high. The base line of certain truncating facets at the end of sprawling spurs may be half a mile or more in length; some of the smaller, spur-splitting ravines are cut off by the connecting wall of the greater facets, so that the ravines are left hanging in facet notches; but the larger valleys are cut down to the facet baseline. The upper part of the facets is inclined at angles of 60° or more and exhibits much bare rock, in strong contrast to the soil-coverd spur sides of less

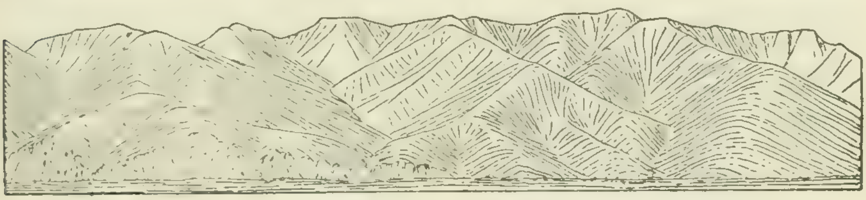

FIG. 3. Truncated and normal spur ends, Swan Range, looking east.

declivity above the facets; the lower part of the facets is flankt with talus. These visible facts of form may be about as well explaind by recent faulting as by recent glacial erosion; but if faulting is appealed to, it must be of much more recent date and of much smaller amount than the great fault by which the mountain mass is set apart from the adjoining depression, for the last of the truncated spurs is followd for a long distance farther south by long, trailing spurs, which descend gradually to the base line and fade away on the plain, thus showing that the main fault is relatively ancient; and it is in front of these dwindling spurs that the belt of moranic hills, springing from the range base near the last of the truncated spurs, swings obliquely away to the southwest. Recently renewd faulting as an origin for the spur-end facets is therefore improbable, for it can hardly be imagind that renewd faulting on an ancient fault line should terminate southward at just that part of a mountain front where the moraine of a great glacier, which decreasd in breadth toward its end, withdrew from the mountain base.

The Galton Range.—The Galton range north of Flathead river notch decreases in height for several miles and takes on an uneven crest line. I suspect that this change is due in part to the scouring overflow of a large branch glacier from the mountains of Glacier National Park. The western slope of the range there and farther north is much less dissected than farther south; and this difference I am disposed to attribute to a northward increase of scouring in the great Kootenai-Flathead glacier; the range front here, instead of being characterized by west-falling valleys and spurs, is markt rather by longitudinal benches, which I took to represent rock layers of somewhat greater resistance than their neighbors, brought into relief by the longitudinal scouring of a huge glacier.

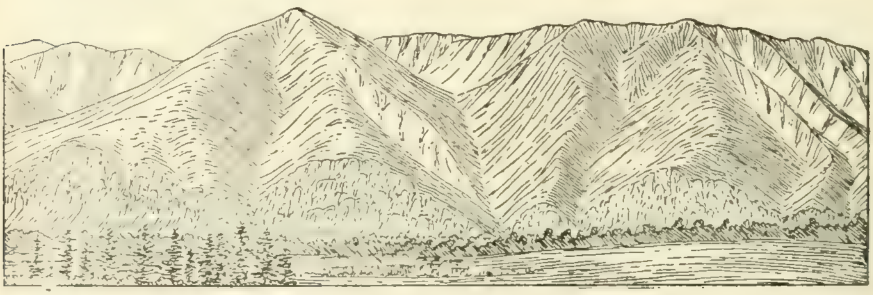

FIG. 4. Nearer view of truncated spur ends, Swan Range.

GLACIER NATIONAL PARK. *Features Due to Glacial Erosion.*—If any doubts are felt as to the truncation of the spur-ends at the western base of the Swan range on the ground that glaciers are incompetent to scour off mountain sides, the doubts should be dispeld by a visit to Glacier National park. Its features of glacial origin are of large scale, and of a kind not found in mountains of normal sculpture. They have been briefly described by Matthes[10] and Willis[11] and more fully by Campbell.[12] I had only a brief view of the district about Lake McDonald at the western entrance to the park, but the features there seen are so unlike those of mountains that have not been glaciated, they are so impossible of production by the processes of normal erosion, and they are so precisely of the kind that glaciers would produce if they had erosiv power, that they can admit of only one interpretation. Among the most manifest of these features are:—the broad trough of Lake McDonald, with its comparativly smooth, concave sides; the sharpend ridges and peaks which rise between broadly opend valley-troughs; the cirques hanging above side-valley troughs, which in turn

[10] F. E. Matthes, The Alps of Montana, Appalachia, X, 1904, pp. 255-76.

[11] B. Willis, Stratigraphy and Structure, Lewis and Livingston Ranges, Montana, *Bull. Geol. Soc. Amer.*, XIII, 1902, pp. 305-352.

[12] M. R. Campbell, The Glacier National Park, *Bull.* 600, *U. S. Geol. Surv.*

hang above larger and more deepend main-valley troughs. In mountains of normal erosion, broad valleys are associated with round crested and well dissected ridges; the occurrence of sharp ridges from which smooth concave slopes descend into broad troughs demands an agency which can have broadend the troughs rapidly enough to undercut the ridge sides and steepen their crests by sapping. Normally eroded broad valleys are joind at grade by open side-valleys; but the great troughs of the park have walls that are almost unbroken for miles together, and when breaks occur, they are not cut down to the level of the trough floor but remain "hanging" above it. Such forms demand an agency that can have occupied the whole breadth of the troughs and scourd their sides longitudinally.

The sharpend ridge crests above the level of glaciation are formd by the intersection of spatulate ravine heads, which widen upward and narrow downward as steep-pitching spur facets advance between them; the spur facets themselves as they widen are slightly but sharply incised by steep-pitching shallow ravines, but as the spur facets and the ravines descend to the level of glacial longitudinal scouring, their salient and reentrant forms weaken, until they are almost lost in the smooth trough sides. Rock structure is abundantly reveald and joints exercise much control in determining details of crest and summit forms, but the course of the steep ravines seems more guided by gravity than by rock structure. The trough sides show the initiation of Postglacial down-slope ravines; a well smoothd trough side next north of the northeast end of Lake McDonald is marked by down-slope "paths" thru strips of forest; the paths are somewhat concave in cross section in their upper part, as if scourd by snow slides; they are increasingly trenchd in their lower part, as if cut by streams. Near the forward-curving base several paths turn aside at a moderate angle from the direct line of descent, as if now avoiding cones of detritus previously formd.

THE FLATHEAD BASIN. *The Flathead Mountains West of the Flathead Plain.*—No local name could be learned for the low mountains, composed of indurated, east-dipping quartzites or sandstones as far as I saw them, which lie west of the Flathead plain and its lake, south of Kalispell; but they belong in a large group to which the name, Flathead mountains, is here given. They rise gradually in maturely dissected or subdued forms, which appear to be of normal origin in the higher western part of the mass, but which bear evident marks of subrecent glaciation along their irregular border, where the spurs advancing between reentrants of variable size consist of small-textured hills and hollows with countless scourd ledges and pluckt cliffs, as well as fluted channels suggestive of the direction of ice motion.

The eastward decrease of height in these mountains is at a much gentler angle than the eastward dip of the strata, and this suggests that the general profile of the mass results from the gentle eastward tilting of an old-mountain lowland or peneplain, so that the elevated part of the peneplain forms the second-cycle mountains of today, and the deprest part descends into the Flathead depression; but the dissection of the tilted mass is now so far advanced in its exposed part that no slanting tabular surfaces remain to attest former peneplanation; nor is anything known to me regarding a scarp or warp by which the uplifted area is limited on the west.

On the northwest of Kalispell, an open embayment enters the low mountains; and here the Great Northern railway originally made its way to the middle of the bent transverse valley of Kootenai river; but this line has been abandond beyond Kalispell in favor of the northern détour of lower grade, above mentiond. The embayment bears the marks of invasion by a small western branch of the Kootenai-Flathead glacier in abundant drift deposits on its floor and in hill-slope scouring along its southern side at least; the northern side was not seen. A small southward reentrant of the embayment contains three lakelets in ascending order, of which the upper or Foy's lake is the largest. All three seem to be shut in by morainic bars. A narrow, flat-floord channel leads southward from the highest lake thru the hills to a still narrower rock-walld gorge, which I took to mark the temporary, constraind course of the outlet of a proglacial lake in the western embayment. If this be correct, similar gorges should occur at higher levels, corresponding to greater overlaps of the constraining glacier on the eastward slope of the low mountains.

Along the western border of the Flathead plain from Kalispell to Somers, and along the western shore of Flathead lake south of Somers, the scourd and pluckt, clift and channeld spurs and hills at the base of the mountains, irregularly advancing into the plain and the lake and gradually disappearing beneath them, are in strong contrast to the evenly truncated spurs of the much higher and steeper Galton range east of the broad depression, and of the higher and steeper Mission range in the southern part of the depression. They give a characteristically irregular shore line to the lake. Near its southern end one of the spurs is prolongd across the lake basin in a series of low, well scourd and pluckt islands. The small-textured irregular features of the spurs and hills here described, taken with their scourd and pluckt, clift and channeld forms, may I believe be accepted as evidence of glacial action, even if striated rock surfaces are not everywhere found. The small-textured features are altogether unlike the systematic soil-coverd slopes of normally dissected spurs and hills of larger texture, such as prevail in the Piedmont belt of Virginia and

the Carolinas; but they are somewhat like the irregularly rugged hills of the deglaciated New Jersey highlands, which as Vermeule long ago pointed out are strongly contrasted with the smoother forms of the highlands south of the terminal moraine; and they correspond well with the irregular hills that I have seen in deglaciated areas of Central France[13] and of North Wales.[14] They are on the other hand distinctly unlike the irregular, small-textured forms of arid erosion, which present minute fretwork with many sharp angles that are wanting in the scourd and pluckt forms of deglaciated hills.

The contrast above mentiond between the smoothly truncated spur ends of the high Swan and Mission ranges on the east and the irregularly scourd spurs and hills of the unnamd low mountains west of the Flathead trough is probably due on the one hand to the steeper preglacial slope of the high ranges, in which the now precipitously truncated spur ends testify to strong longitudinal scouring along the

FIG. 5. Diagram of Mission Range, looking East.

side of the great glacial lobe; and on the other hand to the gentler preglacial slope of the low mountains, in which the rugged hills testify to scouring by an overlapping glacial lobe for a mile or more of breadth.

The Mission Range.—This well defined meridianal range takes its name from the long-establisht Catholic mission of St. Ignatius, west of its southern end. It appears to be composed of the same indurated and deformd sandstones that are so widespread in western Montana; and it may be conceivd as a fault block, some fifty miles in length, broken from the old-mountain peneplain of which so many traces are found hereabouts, uplifted with a gradual southward rise to an altitude of about 10,000 feet near its abrupt southern end in the southern part of the Flathead depression. As seen from the west its submaturely carvd mass, summarized in Fig. 5, shows recent sculpturing by local glaciers in the higher valleys of its lofty southern belt, and heavy scouring by the overlapping end of the Kootenai-Flathead glacier in its low northern belt. Between these two parts is an oblique intermediate belt, of purely normal sculpture. This belt lies beneath the

13 Glacial Erosion in France, Switzerland and Norway, *Proc. Bost. Soc. Nat. Hist.*, xxix, 1900, pp. 273-322.

14 Glacial Erosion in North Wales. *Quart. Journ. Geol. Soc.*, lxv, 1909, pp. 281-350.

high southern belt where features of glacial and of normal sculpture alternate, and above the low northern belt, in which large textured normal features are worn into small textured ledges of glacial scouring. No other mountain range is known to me which exhibits so systematic a combination of these three kinds of forms. For that reason I have given it a fuller description elsewhere.[15]

The Mission range provides desired confirmation for the explanations already offerd in describing the arbitrarily irregular, small textured hills and knobs, channels and hollows along the border of the low mountains west of the Flathead trough, and for the truncated spur ends of the Swan range on the east; for the lower northern slope of the Mission range, where it bears the marks of overriding by the great glacial lobe, exhibits a confusion of small textured forms, most irregularly commingled. The western base of the range, which bears the marks of strong lateral ice-scouring, shows a succession of roughly truncated spur ends alternating with side moraines in the interspur ravines, both of systematically decreasing altitude southward to the point where the superb Polson terminal moraine swings away past the mountain base and bars the adjoining lake basin. Farther south the spurs dwindle away in the piedmont plain, as they did in the southern extension of the Swan range. The contrast between the strikingly irregular western shore of Flathead lake and its relatively simple eastern shoreline is evidently due to the occurrence of small-textured hills and knobs on a glacially scourd surface of moderate declivity on one side of the basin, and of systematically truncated spur ends, worn back to an almost continuous mountain base of steep slope, on the other. The repetition here of the same orderly relation that was observd along the base of the Swan range between decreasing spur-end truncation and a curvd morainic belt tangent to the range base, makes it highly probable that the spur-end facets in both ranges are due to glacial erosion and not to faulting. The bearing of these features on the general problem of sublacustrin glacial erosion is stated at the close of this article. It is interesting to note that in both localities the glacial records change from erosional forms to morainic deposits as advance is made southward from a constraining mountain border to an open plain. The considerable height to which the ice-scourd knobs seem to occur on the northern end of the Mission range makes it probable that a moraine of the eastern ice lobe, into which the great Kootenai-Flathead glacier was divided by this range, should be found several miles up Swan river valley on the east, corresponding to the Polson moraine in the broader basin on the west. Whether

[15] The Mission Range, Montana, *Proc. Nat. Acad. Sci.*, I, 1915, pp. 626-628; also *Geog. Rev.*, II, 1916, pp. 267-288.

Swan lake lies inside or outside of such a moraine I could not learn; but a resident of the district told me that the "pot-hole country," as he called the morainic area, extended into Swan river valley.

Flathead Plain and Lake.—The extensiv Flathead trough, measuring from 12 to 30 miles in width by 110 in length, is smoothly aggraded over most of its extent, both north and south of Flathead lake, by gravels and sands, presumably representing the outwash of the retreating Kootenai-Flathead glacier. The surface has in general the form of a plain, at an altitude of from 2,900 to 3,100 feet; but it is varied by morainic hills in the south, by terraces of small relief along the stream courses, and by occasional basins holding lakes, mostly of small size. The northernmost lake that I saw in this plain was Whitefish, a few miles in length; it appeared to occupy a basin kept free from gravels by an isolated ice-mass. Flathead lake, on the other hand, seems to be the as yet unfilld part of the Flathead trough, elsewhere aggraded. This lake, already described as 27 miles long and from 6 to 15 wide, is reputed to have a depth of several hundred feet; its surface is at an altitude of about 2,900 feet. Flathead and Swan rivers are both forming delta plains at the north end of the lake: Swan river is peculiar in approaching the lake thru a gorge in the low northern end of the Mission range, as if it had been superposed there from a temporary course on the retreating ice sheet; its preglacial course was pretty surely farther north. The broad Flathead trough, now aggraded in the Flathead plain, appears to be an area of down-faulting or down-warping, just as the neighboring mountains are areas of uplift of a preexistent worn-down, old-mountain region. The trough presumably contains stratified deposits washt in from the mountains, beneath the fluvio-glacial gravels and sands that now form its surface plain; but I saw nothing of the underlying strata. Whatever their original thickness, it is probable that they were somewhat eroded by the invading glacier.

The Polson and Mission Moraines.—The Polson moraine, which limits Flathead Lake on the south, is a well defined feature of the Flathead trough. It forms a hilly belt from one to three miles in width, stretching with pronounced southward convexity for eight or ten miles westward from the Mission range; it rises from 300 to 500 feet over the lake, and is sparsely strewn with boulders up to ten feet in diameter. On the east, its northward continuation may be traced in a remarkable series of embankments which bar the normal valleys in the middle part of the Mission range at higher and higher levels, corresponding roughly to the tops of the spur-end facets, until they reach the northward descent of the range crest. The slope of

the ice lobe may be measured by these embankments; it is about 1,000 feet in fifteen or twenty miles. As may be inferd from the account of my route given in the intinerary above, the embankments were seen only from a passing steamer at a distance of from one to three or five miles, yet their form and their arrangement and especially their relation to the Polson moraine were such that I felt no doubt as to their origin. On the west where the country is more open, the northward turn of the moraine could not be surely traced from my points of view. Lower Flathead river, as the outlet of the lake may be called, escapes thru a gap in the southwest part of the moraine, where gray silts are exposed in the banks.

West of the Mission range the Flathead plain continues for twenty or twenty-five miles south of the Polson moraine, and there it may be called the Mission plain; it attains a width of fifteen or twenty miles owing to the withdrawal of the hills on the west. Part of the plain here has a fine brown soil, probably lake silts colored by humus. Gray silts, with local accumulations of gravel, were here cut in the ditches of the Flathead irrigation project of the Reclamation Service. The silts are probably the sediments of Lake Missoula into which the gravels may have been ice-rafted. Farther on, the plain passes into the broad Mission moraine of which a brief account has been given by Elrod.[16] It is of faint relief, dimpled with hundreds of small hollows holding pools after wet weather, and dotted with thousands of boulders. The distance between the Polson and Mission moraines is about twenty miles. The Mission moraine is but little if any higher than the plain to the north of it, but it descends 100 or 200 feet to a lower plain on the south by a slope which seemd to be convex in plan. The lower plain is limited on the south by a range of subdued hills of deformd quartzitic strata, beyond which is the valley of Jocko creek, followd by the Northern Pacific railway. Flathead river turns westward from the basin plain and then again southward thru the hills to the point where, receiving Jocko creek—the town of Dixon is at the junction—it tends to follow the long northwestward valley that farther on is entered by Clark fork.

Agriculture on the Flathead Plains.—The plains of the Flathead trough, like many other intermont basin plains in Montana, have attracted a thriving agricultural population, which is destind to increase, especially in the areas served by the irrigation ditches of the Flathead project, as constructed or pland by the Reclamation Service. This project provides "for the irrigation of about 152,000

[16] M. F. Elrod, The Physiography of the Flathead Region, Bull. Univ. Montana, *Biol. Ser.*, 1903, pp. 197-203.

acres of land in various parts of what was the Flathead Indian reservation, water being diverted from creeks and rivers rising in the Mission mountains and conducted by canals directly to the land and to reservoirs for storage of floods. The gravity supply will be supplemented when necessary by pumping from Flathead lake. The area of the drainage basin is approximately 8,000 square miles." Roads here follow mile-square section lines, except where they are constraind to turn in crossing the bordering hills and ridges. A branch from the Great Northern railway, which crosses the northern part of the plains, extends to Kalispell, the chief town of the district, and to Sommers at the northwestern angle of Flathead lake; Somers and Polson are connected by steamboat service on the lake; from Polson a quick crossing may be made by automobile southward to Ravalli on the Northern Pacific railway. The mountains afford an abundant supply of timber and summer pasture. The Montana National Bison range, enclosed by a strong fence, occupies about 30 square miles on the hills between the south end of the basin and the valley of Jocko creek.

THE KOOTENAI-PEND OREILLE DEPRESSION. *The Trough of Kootenai Lake.*—We next pass to the Purcell trench in the Kootenai-Pend Oreille region, and begin the account of it at the northernmost point visited on my excursion. Kootenai lake, beginning 18 miles north of the international boundary, occupies the deepest part of one of several almost mature glacial troughs, overdeepend by the great trunk glacier of a number of recently extinct glacial systems. The troughs follow the main valleys of the Selkirk mountains, which as a whole are submaturely dissected to strong relief of prevailingly insequent pattern. The lake is 65 miles long north and south and two or three miles wide; it is said to have been sounded to a depth of 800 feet; its surface stands at 1,760 feet above sea level, while the adjoining mountainous highland has summits that reach elevations of 8,000 feet and more. After Kootenai river enters the trough from the east, it turns sharply to the north—Bonners Ferry lies at the elbow—and flows to the lake over a delta plain some 30 miles in length. The lower Kootenai, which forms the lake outlet westward to the Columbia river, escapes by a lateral distributary of the main trough, into which a narrow and comparatively shallow arm of the lake projects a few miles from the lake mid-length. Nelson lies where the river begins.

Glacial Origin of the Lake Trough.—The river and lake trough is described as almost mature because, altho the adjoining mountain spurs are strongly truncated, the trough sides still preserve some of

the crags and knobs and promontories of glacial immaturity. This appeard to be particularly the case in the north end of the basin where the shore lines, as seen from the middle of the lake, seemd to be more varied by rocky salients than farther south; a well-scourd rocky island rises near the middle of the lake. Two bays indent the lake shores; one is near the middle of its eastern side; the other is of more irregular pattern on the western side. In the southern half of the basin the unconsumed knobs and ledges are smaller, and the scourd, pluckt and channeld outlines of their rounded, small-textured forms express very emphatically the advanced stage of the severe longitudinal scouring to which they are due. Viewd in the larger way, the sides of this part of the trough rise in concave slopes to slanting triangular facets of unlike size which truncate adjacent mountain spurs and leave hanging between them the shortend or betrunkt upper parts of numerous normal valleys; but some of the high-level side openings of the main trough are hanging glacial troughs of well developed catenary cross-section; a fine example of this kind is seen west of the lake near the entrance of Kootenai river. Slightly incised, postglacial chasms descend from the normal hanging valleys and side troughs toward the lake, where small gravel deltas are forming. The high-level spur facets are remarkably well alignd, so that they unite downward below the valley notches in the longitudinally continuous, concave trough-sides, which give the southern half of the lake a comparatively simple outline. The shoreline is smoothest where it follows patches of drift or growing gravel deltas; its irregularities are numerous but of small texture where it contours along bare rock ledges.

Trough-Side Clefts.—The rocky slopes of the trough side often show oblique clefts, which intersect so as to outline an irregular network with lozenge-shaped meshes, and thus indicate the influence of lines of weakness such as are determind by master joints or faults in guiding the processes of glacial scouring and plucking. Similar forms are to be seen on the deglaciated trough sides of Lake Como. The oblique network of joint clefts thus produced further indicates, to my reading, that joints and fissures are not as a rule potent factors in the guidance of valley erosion, because the branch work of valley lines on a mountain side, where each line follows a direction of maximum slope, is essentially unlike the irregular criss-cross network of joint clefts, the members of which usually depart from the direction of maximum slope. Joints and fissures thus appear to be important in guiding the scouring and plucking action of glacial erosion, much in the same way that they are important in guiding the normal weathering and erosion of clefts in steep and bare rock surfaces, from which

the rock waste is removed about as fast as it is detached; but as soon as a surface that is attackt by normal weathering and erosion is worn back to a gentle slope, so that rock waste begins to cloak it, and whenever a stream course is curved so that lateral erosion is effectiv, the importance of erosion along joints and fissures becomes subordinate to the development of stream-guided valley lines. From this time on, the stream-guided lines become dominant with but little regard to joints and small faults. It is of course true that a master fault may be borderd by so wide a belt of brecciated rock, that a subsequent valley will be developd along it; but it seems to be equally true that, in a jointed or fissured rock mass, such as that of the mountains which enclose the Kootenai trough, the ordinary joints or fissures will not suffice to guide the gentler process of normal erosion, by which branching normal valleys are formd, even tho they have guided glacial scouring.

Hanging Lateral Valleys.—The smaller hanging valleys of normal erosion are abundant, characteristic, and pleasing elements of the trough sides at high levels. They open upwards in half-funnel forms between the normally graded side slopes of the truncated spurs. The larger normal valleys are cut down to a lower level, but seldom so low as the lake shore; they subdivide headward into the mountains in the pleasingly irregular fashion that characterizes insequent drainage. But besides the hanging normal valleys of V-shaped cross section, there are, as above noted, several hanging lateral glacial troughs, with catenary cross-section; and these are of two kinds, incoming or tributary, and outgoing or distributary. Some of the smaller ones of the first kind hang well above the lake surface; other larger ones are cut down nearly as low as the lake. The single example of a hanging distributary is the one above mentiond that opens to the west near the middle of the trough; the distributary trough is somewhat deeper than the lake surface at its beginning and is therefore slightly drownd in the narrow, river-like western arm of the lake. Its depth decreases westward to a flat col, across which the lake arm gives forth the lake outlet.

Evidently a relativly small volume of ice turnd west here, and the larger volume went on south; otherwise, the western arm should be the deep main trough and the southern trough should be a shallow distributary arm. The town of Nelson lies where the lake-arm becomes a river; a little farther on the river descends in falls on its way to the Arrow lakes and the deeper trough of the Columbia; hence the glacial distributary that here left the Kootenai glacier connected it, in the net-work fashion that is characteristic of ice drainage, with the Columbia glacier. Two fine incoming glacial troughs hang well

above the west-arm distributary in its southern side, just as it hangs well above the main lake bottom; and in this two-story discordance is to be found strong evidence of great overdeepening in the main lake trough.

The Nelson Distributary Trough.—As only a small part of the west-arm or Nelson distributary is submerged where it leaves the main lake, almost its entire catenary cross section is visible: its steepest slopes, although steeper than the sides of the normally graded mountains that rise above them, probably do not exceed 30° or 35°. Hence the trough has little resemblance to the letter U, with which some glacial troughs, like those of Lauterbrunnen in the Alps and parts of the Sogne fiord in Norway, may be compared. The difference of origin between true U-troughs and those of more open catenary form may perhaps be explaind by supposing that the former represent a youthful stage of active deepening by a rapidly moving and strongly eroding glacier, preparatory to a later stage of widening; while the latter exhibit a mature stage of gradual widening, whether preceded by an active deepening or not.

The catenary cross section of the west-arm distributary trough warrants the inference of a similar form for the main trough. If a cross-section curve is begun in the higher slopes of the trough sides, which descend at angles of 30° or 25°, and is continued beneath the lake surface which is three or four miles in width, the depth of the rock trough they indicate will be significantly greater than the reported depth of 800 feet for the lake bottom. The lake may be somewhat shoald by glacial drift or outwasht deposits.

It may be well to point out that the production of such a lake as Kootenai by the warping of a normal, maturely widend preglacial valley is, as Wallace pointed out years ago, an impossibility. A maturely widend valley of normal erosion must have all its side valleys cut down so deep that their streams unite with the main stream at accordant levels; and if such a valley were warpt, so as to hold a lake, the lake shoreline would necessarily possess as many side bays as there are side valleys to be drownd: but Kootenai lake has very few side bays; and such bays as it possesses are probably submerged hanging lateral troughs.

Lakes Kootenai and Maggiore.—Except for the absence of all signs of human occupation, such as villages, fields, roads, paths, and terraces, and except for differences of vegetation, the mountain sides of Kootenai trough along its southern half present many systematic resemblances to the mountain sides of Lake Maggiore in the Italian Alps, as in all such great glacial troughs, one may note the prevalence

of simple shorelines, with few promontories and fewer embayments; the continuity and the simple form of the slanting trough sides, cut in chasms only where streams descend from the hanging valleys of normal form, and deeply breachd only at the entrance of hanging glacial troughs; the occurrence of open lake arms in submerged tributary or distributary troughs, the broad lake arm in the hanging tributary trough of Lake Maggiore, corresponding to the narrower lake arm in the hanging distributary trough of Kootenai; the concave ascent of the trough-side slopes into triangular facets by which the mountain spurs are so evenly truncated; the occurrence of occasional unconsumed knobs and sills on the trough-side slopes, alternating with occasional sheets of drift, and the more common occurrence of well scourd rock ledges with gently convex profiles on lines parallel to the lake shore; the scourd-out network of oblique clefts on the trough sides, as if disclosing the master joints or fissures of the mountain mass; the normal forms of the hanging lateral valleys between the truncated spurs; the foaming torrents that cascade from the hanging valleys down the trough-sides; and the trifling amount of Postglacial change, limited chiefly to the torrent-cut chasms beneath the hanging valleys and to the small deltas at the foot of the clefts.

From Kootenai Lake to Lake Pend Oreille.—As one travels southward along the delta-plain of the Kootenai trough, the trough-side wall continues to limit the mountains on the west, until as one ascends over a flat drift divide to the broad plain north of Lake Pend Oreille, features of glacial origin in the enclosing mountains are for a time of less and less distinctness. South of the international boundary as well as north, the Canadian name, Selkirk mountains, may be applied to the mountain mass on the west. Several of the higher summits, above 7,000 feet, some miles west of the trough, show sharpend summits between the widend, almost confluent floors of adjacent cirques; it is to be presumed that glacial troughs descend from such cirques. The summits of less altitude are of dome-like form and seem to be remnants of an uplifted mass of moderate relief, never smooth enough to be called a peneplain, and now submaturely incised by normal valleys.

The eastern base line of the mountain mass all along the western side of the great trough is singularly simple, being without spurs that stretch forward into the trough plain, and almost without re-entrants that indent the mountain border. Many maturely open normal valleys terminate in hanging fashion on the trough side or mountain face, and their streams descend the lower slope in narrow chasms that hardly interrupt the continuity of the pluckt, scourd, and cleft mountain slope; but glaciated side valleys are not numerous.

In the middle part of the Kootenai-Pend Oreille depression, where its breadth is increased by the recession of the mountains on the east of it, as stated below, the mountain border on the west may perhaps be interpreted as a north-south fault-line scarp, maturely dissected aloft and simplified by glacial scouring on its lower slopes; but in the absence of information regarding the structure of the district this suggestion cannot now be tested.

The Purcell mountains on the east side of the Kootenai trough recede eastward about midway from the lake head to the Bonner elbow, and thus a depression 12 or 15 miles in width is opend. The village of Creston is at the northern limit of the widend depression, which is well defined; the southern limit is vaguely markt beyond Bonners Ferry. The recession begins where a large glaciated trough, that of Goat river, comes in from the highlands on the northeast, and it is conceivable that the width of the depression is due to the junction of this trough with the greater one. The eastern mountain wall farther southward is at first very bold, rising to a plateau-like highland and giving suggestion of horizontal structure in its high cliffs above great talus slopes; a fine hanging valley opens at mid-height in the cliffs. The southern extension of this mountain mass is interrupted by the east-west transverse valley by which Kootenai river flows from its eastern to its western trough at Bonners Ferry, and the name, Purcell range, is limited to the area north of this valley. The name, Cabinet range, is given to the mountains following on the south. They were not well seen on my trip, but occasional views of their flanks showd abundant signs of ice scouring.

The Creston Terrace.—The eastern half of the broadend Kootenai depression from Creston to Bonners Ferry is occupied by an extensiv terrace at an altitude of 2,200 feet, here called the Creston terrace, of which there is no sign farther north along either side of the lake trough. The terrace deposits perhaps result from the aggradation of the space evacuated by the tributary Goat-river glacier, while the main Kootenai glacier still extended farther south. Goat river, on emerging from its mature mountain trough at the northeastern angle of the depression and cutting thru the terrace beds, is locally superposed on the underlying rocks and has there cut a deep and narrow chasm, which is spand by a high bridge on the Crows Nest line of the Canadian Pacific railway; farther down stream the river has eroded a fairly open valley in the terrace.

A large tributary of the Kootenai glacier must have come down Goat-river trough, as the trough sides are spurless and maturely smoothd in their lower slopes, and notcht by hanging valleys in their upper slopes. The Crows Nest line enters the Goat-river trough

about 25 miles from Creston by a hanging branch trough from the east, and slants down the drift-patcht slope of the southern trough wall beneath the level of its lateral hanging valleys. When the terrace in the Kootenai depression is reacht, the railway crosses its high surface westward to the slope by which it falls off to the Kootenai delta plain; there Creston stands; then turning northward, the railway slants along the side slope of the Kootenai trough, again beneath the level of several hanging valleys, and descends to the level of the Kootenai delta plain; thus for the second time avoiding the detours or viaducts that would be necessitated in passing along the side wall of a maturely open normal valley, in which the side valleys would be cut down to the main valley bottom.

The Kootenai Delta Plain.—In the stretch of 36 miles from the Bonner elbow of the Kootenai to Kootenai lake, the river flows northward through a smooth alluvial flood plain and delta of about the same width as the lake. On the west the mountains, as above described, rise from the plain just as they rise from the lake farther north; and so they rise on the east also from that part of the flood plain which lies between the head of the lake and the Creston angle where the eastern recession of the mountains begins. The rest of the eastern side of the plain is limited by the slope of the high terrace. The base of the terrace seems to be defined by occasional outcropping ledges of granite, that have defended the surviving part of the terrace from being undercut by the swinging river. It does not seem probable, however, that the terrace ever extended completely across the whole trough, for in that case remnants of it should be seen along the western trough-side where none were noted.

The delta plain offers extensiv meadows for pasture, but is subject to floods that have discouraged agriculture. It is proposed to submerge a good part of the plain by raising the level of Kootenai lake by a dam across its outlet at the rapids a short distance below Nelson on the western lake-arm; but the raisd lake would extend across the international boundary, and the legal questions involvd in this project have causd delay.

The Drift Divide Between Kootenai and Pend Oreille Lakes.—Next southwest of Bonners Ferry, an abandond meander of the Kootenai is mapt as Mirror Lake. About midway from Bonners Ferry to Lake Pend Oreille, the Purcell depression, here called the Kootenai trough, is narrowd to four and even to two miles; it is here occupied by drift and silts, increasing in altitude southward, in which a small stream has accomplisht a moderate amount of terracing. The drift divide at the head of this stream is of somewhat irregular form,

and is very likely formd in good measure of morainic deposits. It has an altitude of 2,253 feet where crost by the Great Northern railway at Elmira station, and there separates the delta plain of the Kootenai, which slopes gently northward to Kootenai lake, 1,760 feet in altitude, as above described, from a higher plain that slopes gently southward for ten miles to Lake Pend Oreille, 2,051 feet in altitude. This higher plain is occasionally interrupted by rocky knobs, and is slightly dissected by narrow valleys, which show bedded sands or clays. The large extent of the plain suggests that the Kootenai-Pend Oreille glacier stood for a considerable time near the Elmira divide; and it is possible that the moraine there corresponds in time with the Polson moraine of the Kootenai-Flathead glacier. This possibility will be further considerd in the latest division of the essay. The town of Sandpoint lies at the southern margin of the plain where an arm of the lake turns westward to its outlet by Lower Clark fork. Here the Northern Pacific railway, that has followd down the valley of Upper Clark fork, yet to be described, and rounded the northern shore of the lake past Sandpoint, crosses the western arm on trestle work; the Great Northern railway which has come southward from the Bonners elbow of Kootenai river, follows the outlet and crosses it a few miles west of the lake. A branch of the Canadian Pacific turns from the Crows Nest line before it enters Goat-river trough, and also passes by Bonners Ferry and Sandpoint on the way to Spokane. Before the formation of the Elmira-Sandpoint plain the lake must have been much longer than it is now. The level of this plain is so nearly the same as that of the high silt terrace east of Kootenai delta plain, that both were probably formd in the same proglacial lake—a large expansion of Lake Pend Oreille—when the westward discharge of Kootenai lake and river past Nelson was still obstructed by ice. The delta plain of the Kootenai is at a lower level and evidently of later origin.

The Transverse Valley of Kootenai River.—The eastern half of the bent transverse valley by which Kootenai river crosses the southern extension of the Selkirk Mountains from the Kootenai-Flathead depression on the east to the Kootenai-Pend Oreille depression on the west was traversd by train on the Great Northern railway after dark; the following notes refer to the western half, from Libby (2,205′) in the midst of the mountains to Bonners Ferry (1,761′). At Libbey there is an open depression, in part occupied by heavy deposits of white silts and terraced by a stream from the southeast: it was by a pass at the head of this stream that the original location of the Great Northern railway came from Kalispell to Libby. Southwest of Libby, glimpses were caught of a group of high summits in

the Cabinet mountains with Alpine forms, as if strongly sculptured by former glaciers. Not far down the valley from Libbey four tributary valleys enter from the north; the first and fourth join the main valley at accordant levels as normal tributaries; the second and third join at discordant levels as hanging tributaries; and hereabouts the main valley has a rather well developd trough form, scourd in bedded rocks that dip upstream.

Kootenai Falls are a little farther down stream; there the river suddenly changes its habit from that of a wide, smoothly flowing current on the trough floor, to that of a narrow and impetuous torrent in a ragged gorge that is incised beneath the trough floor. The falls at the point of change may be 20 or 30 feet in height, but a rapid descent is continued for some distance down stream. Remnants of the trough floor are seen in the form of ragged rock benches on either side of the river for half a mile or more below the falls: then the valley widens, as if the rocks were weaker. In a valley of normal erosion it would be difficult if not impossible to account for these singular features without postulating a recent warping of a formerly mature valley, in such manner that the river should be locally revived to deeper erosion; but in a deglaciated valley, which evidently owes its trough-like form as well as its depth below some of its tributaries to glacial erosion, it is legitimate to assume that the scourd floor of the trough departs from the continuous down grade that a river would produce, and that a river flowing thru such a trough would incise a gorge wherever the rock floor has a sufficient slope.

On approaching Bonners Ferry, the river is confined in a narrow gorge on the south of the high terrace that there occupies the broadend Kootenai trough: the gorge appears to be the result of superposition thru the terrace deposits, which probably bury the former river valley. The gorge is well seen from the Canadian Pacific line, which skirts the edge of the high terrace in ascending northeastward from Bonners Ferry.

The Pend-Oreille-Spokane Region. *The Distributaries of the Kootenai-Pend Oreille Glacier.*—The irregular distribution of mountains and valleys in the region into which the great Kootenai-Pend Oreille glacier advanced—here called the Pend Oreille-Spokane region—resulted in its subdivision there into several out-going branches or distributaries. A distributary crept down the valley of Lower Clark fork for some twenty-five miles, and supplied a large volume of washt drift, remnants of which now form extensiv terraces; this branch seems to have moved slowly around or over the isolated mountains that obstructed its course; it has not left conspicuous marks of its passage. A southwestern distributary advanced an unde-

termind distance between detacht ridges and knobs. A southern distributary continued some 20 miles, overdeepend the trough of Lake Pend Oreille and supplied from its extremity, with the aid of the southwestern distributary, the vast volume of gravel and sand that forms an outwash plain as far as Spokane. The southeastern distributary ascended the valley of Upper Clark fork for an undetermind distance, and with the aid of local glaciers greatly modified the form of the valley sides by erosion. The troughd valley was afterwards encumberd by large volumes of morainic and outwasht deposits during the waning of the invading glaciers.

It was the work of the southeastern distributary of the great Kootenai-Pend Oreille glacier and of local glaciers farther up the Clark fork valley that formd the central object of my excursion. Moreover it appears to have been this distributary of the great glacier which, separating from the southern distributary where the ice surface had an altitude of somewhat more than 4,000 feet, bard the waters of Lake Missoula in the branch valleys of Upper Clark fork. Singularly enough it seems to have been beneath the waters of this lake that the ice in the Upper Clark fork valley did its highly significant erosiv work, as will be further set forth below.

The Southwestern Distributaries of the Kootenai-Pend Oreille Glacier.—The description of these glacial distributaries is difficult from the irregularity of their courses and from the lack of names for the isolated mountains by which they were subdivided, to say nothing of the shortness of the time that I could give to their examination. Fig. 1 serves to show the general distribution of the smaller mountain masses between the strong range (4,500′) which extends northward from the Chilco mass (5,625′) along the west side of Lake Pend Oreille, the still stronger Selkirk Mountains on the northwest (6,700′), and the Mt. Carlton (5,508′) outpost mass (C. Fig. 1) on the southwest. The names Curtis, Huckleberry and Algoma (S., H., A., Fig. 1), are here adopted for smaller unnamed mountains of intermediate position, from the names given on the maps for local features near them.

Soon after leaving Sandpoint on the way down Lower Clark fork valley, glacial scouring, well assured though not so strong as north of Sandpoint, was seen along the southeastern flanks of the Selkirk Mountains nearly to their southernmost extremity; drift seemd to be packt into their embayments; the mountain tops and the higher slopes have normal forms; the valley bottom is occupied with stratified clays. Ice-scourd slopes were noted on the northern flanks of Algoma and Huckleberry mountains, southeast of the river. Hoodoo valley, between Curtis and Huckleberry mountains, was not visited;

it is followd by the Canadian Pacific branch line, known as the Spokane and International railway, and from the details of the topographic maps it appears to have been enterd southward by a branch of the western glacial distributary here considerd; for the marshy depression (2,200′) on its east side, and the marshy basin high (3,000′) on the east flank of the Curtis mass both suggest glacial disturbance of normal drainage. More significant still is the heavy tabular body of morainic drift (2,500′) with large boulders, east of the Mt. Carlton mass, probably to be associated with the southwestern glacial distributary, as will be further described in a section concerning the Lone Mountain gravel mesa. The peculiar, river-like Hoodoo lake will be referd to in the section on the outwasht gravels of the southern glacial arm. A rather small branch of the southwestern glacial distributary may have past between the West Pend Oreille range and the Huckleberry mass, where Cocolalla lake now lies; the Northern Pacific railway follows this depression, but it was after dark when I ran through it.

Lower Clark fork turns northwest after passing between the southern end of the Selkirk Mountains and Curtis mountain. No signs of glacial action were there noted, but as the high terrace (2,300′) which seems to consist of outwash from the ice, does not begin for a few miles down the river, it is likely that a lobe of the ice advanced at least as far as the terrace head, altho marks of erosiv action are not there evident. The river has now cut down more than 200 feet into the high terrace, and is superposed near the terrace head on a rock ledge, in which it has cut three narrow notches; here are Albany falls, where the Great Northern railway crosses the river; two miles farther down stream, the town of Newport lies on the terrace which continues southward along the west flank of the Mt. Carlton mass, past which the railway runs on the way to Spokane. A singular feature here noted was that a head branch of Little Spokane river rises close to Newport and flows on its southward course thru a narrow, rock-walld gorge with much fresh talus, in part occupied by a long narrow lake. This had the appearance of being the work of Clark fork or of a distributary of that river, temporarily deflected southwestward during the aggradation of its high terrace. If so, the return of the river to the northwestward course below Newport is probably to be explaind by the easier trenching of the terrace deposits in that direction than southward. Much field study remains to be done here.

Lake Pend Oreille and its Glacier.—The heavy deposits of clays and silts which form the broad plain (21-2290′) north of Lake Pend Oreille (2051′) have a length of about ten miles; if they

were absent, the lake would probably drain northward into the trough excavated by the main body of the Kootenai-Pend Oreille glacier, for Kootenai lake is nearly 300 feet lower than Lake Pend Oreille. The western five-mile arm of the lake at its northern end may be associated with the western and southwestern distributaries of the glacier; the northern part of the lake, as far as the delta at the mouth of Upper Clark fork, may be regarded as the work of the undivided southern and southeastern glacial distributaries, before their separation; the curvd remainder of the trough, some twenty miles in length and two or three miles in width, is the work of the southern glacial distributary alone, and includes the finest part of the lake, as rated in terms of the bold mass of its mountain walls. A depth of 1,300 feet is said to have been measured near the middle of the lake by competent recorders. Unfortunately I saw the north end of the lake only near the close of a hazy afternoon, the southern end only from the moraine at its southwestern extremity, and the middle part not at all; hence certain details here following are taken from the Priest lake, Cataldo and Rathdrum topographic map-sheets.

Oversteepened Lake-Trough Walls.—The precipitous slopes of the trough sides, seen in the oversteepend mountain walls above the lake surface, are remarkably free from projecting spurs, and suggest a strong measure of vertical glacial erosion or overdeepening of the lake bottom, as well as of lateral erosion or oversteepening of the preglacial valley sides. The glacial erosion of the trough sides is especially striking in the somewhat amphitheatral mountain walls on the convex sides of the curvd lake. One of the steepest walls is next west of the entrance of Clark fork. Here the enclosing mountain mass, which is represented on the map as having abundant normally branching valleys and spurs on the non-glaciated slope south of its crest line (4,500′) where it appears to have been out of reach of the ice, presents on the north a smooth wall, without significant salient or reentrants, which descends 2,000 or 2,500 feet in a slope of about 35° to a simple shore line. High on this steep wall is the probable location of the outlet of Lake Missoula, as will be further stated in a later section. The first oversteepend concave wall is on the west side of the lake, a few miles farther south; here again a smoothd mountain side, 1,000 or 2,000 feet in height, descends to a simple shore line; but in the mid-length of this wall, where the crest height is 3,000 feet or a little less, the ice probably overflowd westward: on the opposit or eastern side of the lake the mountain slope is more dissected and less precipitous. The long curve of the lake on the southeast is enclosed by a well clift mountain side, except where the

two valleys of North and South Gold creeks enter from the east and south. To the north of these valleys, the ice-scourd walls are of moderate height, but their abrupt descent is in striking contrast to the normally carvd mountain slopes above them; a normal late-mature valley has here lost its lower part, and hangs some 1,500 feet over the lake bottom. The wall along the south end of the lake is remarkably simple for most of its length, and forms a well-matured trough-side; its height increases westward from the Gold creek valleys, and where the highest part of the enclosing slopes, beneath Bernard peak (5,200′) at the north end of Chilco mountain, is undercut, there is a precipitous descent of 2,500 feet to an exceptionally smooth shore line. Only a few hundred feet of the mountain top retain their normal slopes above the clift wall, and these are encroachd upon by activly retrogressiv ravines. West of Bernard peak, the ice-scourd wall rapidly decreases in height, but is maintaind as a well defined feature to the very extremity of the lake. The convex wall on the northwest side of the southern turn, culminating in Cape Horn peak, is well scourd, and at its sharpest turn is almost as steep for 1,500 feet above the lake as the concave wall.

Estimate of Glacial Overdeepening in Lake Pend Oreille.—It would be difficult to imagin a group of forms more convincingly demonstrativ of strong glacial erosion along a preglacial valley than these systematically steepend, spurless mountain walls, with normal forms and hanging side valleys above them and with a deep lake basin between them, all in a district where the mountains in general have subdued forms of moderate slope, with well graded branching spurs, separated by branching valleys of accordant junctions. The amount of deepening that the preglacial valley sufferd may be roughly estimated as follows:—At the southeastern curve of the lake shore, near its southern end, the valleys of North and South Gold creeks, above mentiond, enter from hills and mountains of apparently normal, late-mature forms; if these valleys were invaded by ice, the work done there must have been small. The valleys seemd, as well as I could judge from a point of sight to the west, to be about as deep as the lake surface; the village of Lake View lies at their mouth a little above the level of the lake. Now inasmuch as all the mountain forms hereabouts, outside of the glaciated areas, show normal forms of late mature, well subdued expression, it follows that these branch valleys from the east and south must have been, in preglacial times, about as deep as the larger valley that they joind in what is now the lake trough; and further, that as the lake is, according to recent soundings, 1,300 feet deep, 1,000 feet may be taken as a fair minimum measure of the amount of glacial overdeepening that the pre-

glacial valley has sufferd in its conversion into a glacial trough. The lateral erosion of the preglacial valley sides at the level of the lake surface must have been much more than 1,000 feet at several points.

It should be noted that altho the surface of Lake Pend Oreille (2,051′) is almost 300 feet above that of Kootenai lake (1,760′), the bottom of the southern lake (2,051-1,300 or 751′) is lower than the bottom of the northern lake (1,760-800′, or 960′), as far as present soundings go. It thus becomes all the more probable that the divide (2,250′) between Bonners Ferry and Lake Pend Oreille is bankt with morainic drift deposits of great thickness; otherwise the two lake troughs might be confluent.

The Moraine at the South End of Lake Pend Oreille.—The southwestern end of the lake is bard by a heavy moraine, and divided by a blunt morainic cusp into two bays, of which the southern one, borderd on its southern side by the ice-scourd wall above mentiond, is two and a half miles long without a local name, and the northern one, mapt as Squaw bay with the village of Bay View at its end, is a mile and a half long. A branch of the Spokane and International railway rounds the morainic hills and descends nearly to lake level at Bay View; limestone quarries are workt near-by, and cement quarries are opend in the southeastern wall of the lake. For several miles west of the lake end, heavy morainic deposits occupy what might otherwise be an open extension of the lake trough. The uneven surface of the moraine is sparsely dotted with boulders, often five or ten feet and occasionally fifteen feet in diameter. The morainic hills gradually rise 350 feet over the lake to an elevation of something more than 2,400 feet: and there fall toward the beginning of the great Pend Oreille-Spokane outwash plain, to which the next section is devoted.

The Pend Oreille-Spokane Outwash Plain.—Lake Pend Oreille lies near the western border of the Rocky Mountain system: to the east of it, the mountainous highlands are relatively continuous for many miles; to the west they are divided into a number of small isolated masses, separated by irregular depressions, as in Fig. 1. The mountain slopes bordering these open depressions, as well as some of the valleys that penetrate farther eastward into the mountainous highland, are discontinuously terraced by lava-flow benches, from which it must be inferd that, after the mountains which enclose the depressions had assumed much of their present form by long continued erosion, they were encroacht upon by and partly submerged beneath the successiv flows of the rising floods of lava which built up the vast lava plains of the Columbia basin; and that the lava plains

were afterwards greatly dissected and the intermont depressions were again widely opend along the margin of the mountainous highlands. It is one of these re-excavated depressions, limited on the southeast by the Coeur d'Alene mountain mass, by the Mica-peak mass on the south, and on the northwest by the outlying Mount Carlton mass, that is heavily filld to a width of from four to ten miles as far as Spokane and beyond, with the great gravel outwash plain of the Pend Oreille glacier. Thus the visible depth of the depression between the mountains is much decreast. The altitude of the plain at its beginning near the end of Lake Pend Oreille is about 2,400 feet; at Spokane, 45 miles to the southwest, it is about 2,000 feet. Its depth is unknown by direct measurement, but in a later paragraph on Lake Coeur d'Alene, evidence will be given to show that a depth of over 400 feet is probable.

Many boulders among the gravels are from two to four feet in diameter, and some are still larger; hence the glacial river by which such blocks were washt twenty or thirty miles from the end of the ice must have been large and vigorous: it may well have been so if it discharged as ice water all or nearly all the huge tongue of ice that crept southward through the great trough of Lake Pend Oreille.

Steepend Mountain Flanks Bordering the Outwash Plain.—Further evidence of the vigor of the ice-water river is found in the steepening or refreshment of the slope of a lava bench that flanks the mountains on the east, some twelve or more miles southwest of the end of the lake. Instead of presenting a graded slope, such as commonly borders the residual benches of the maturely dissected lava sheets elsewhere, the bench here breaks off to the gravel plain in a steep scarp, as if it had been actively scourd and undercut by the current of a strong stream along its base. The scarp of a lava mesa west of Spokane is similarly refresht where it borders the gravel plain. Other instances of similarly undercut slopes will be mentiond below.

The brief views that I had of two side valleys, both joining the main trough at Spokane—one, that of Little Spokane river, to the north, the other, that of Latah (formerly Hangman's) creek, to the south—showd the outwash there to be composed chiefly of finer gravels and sands, as might be expected from their position to one side or the other of the main outwash. Bricks are made from clays that occur in a side valley eroded in the lava plateau a few miles southwest of Spokane: I had no opportunity of examining the clays, but venture to suppose that they are the fine sediments which slowly accumulated in the side valley while it was ponded by the more rapidly aggrading gravels of the main outwash.

The Broad Channel in the Outwash Plain.— The original surface of the main outwash plain is now interrupted by a broadly eroded channel having depths of 30, 50 or 100 feet, and the channel thus appears to be borderd by terraces, wider on the southeast side toward the main body of the Coeur d'Alene mountains and on the south toward the advancing mass of Mica peak; narrower on the northwest along the base of the isolated Mt. Carlton mass. As no stream now follows the greater length of the broadly eroded channel between the terraces, the excavation may be regarded as the work of a clarified and degrading ice-water river, issuing on the gravel plain from the southern end of Lake Pend Oreille at a level somewhat below 2,500 feet, when the ice had melted back a few miles but not far enough to open a lower passage farther north where the lake finds it present outlet; for such a stream would have left its sediments in the lake, and would therefore be able to cut a channel thru the plain which its unfilterd predecessor had built up.

Hoodoo Lake.—While the channel of the outwash plain was going on, the lateral streams, such as Little Spokane river and Latah creek, terraced the finer deposits of their lateral valleys. Some further details in this connection are given in a later section in which the lakes enclosed by the gravel outwash are described. Mention may be made in this connection of a long and narrow depression, half a mile or a mile in width at an altitude of between 2,100 and 2,200 feet, running west from Squaw bay, the northern one of the two southwestern bays of Lake Pend Oreille, for about ten miles, and then northward for ten miles more to Clark fork. The northward turn of this depression is occupied for some seven miles by the narrow and marshy Hoodoo lake. This may mark a temporary lake outlet of late glacial date. I saw only the eastern part of the depression; the description of the rest is taken from the maps of the Rathdrum and Sandpoint quadrangles.

Spokane River.—Some ten or fifteen miles east of Spokane the river of the same name, coming from Lake Coeur d'Alene, enters the broad channel in the gravel plain, and continues on a smaller scale the work of sweeping away the gravels that had been previously begun by the extinct ice-water river. The depth of incision by Spokane river east of the city is however limited by its superposition on a lava bed within the city limits, of which more is said below. When one crosses the outwash plain from north to south, the channel is easily recognized; but when one looks eastward along the plain, as one may from the rim of the lava plateau west of Spokane, the channel can hardly be detected, except in the immediate foreground: the out-

wash then seems to be a smooth plain. When this district was first settled the plain was regarded as a barren waste; it is now partly irrigated and occupied by thriving farms and orchards.

The Lone Mountain Gravel Mesa.—Lone mountain (L. Fig. 1), two miles in diameter and 3,400 feet in altitude, rises nearly 1,000 feet over the general surface of the gravel outwash, twelve miles southwest of the long arm of Lake Pend Oreille and three miles east of the Mt. Carlton mass. When viewd from the plain on the southeast (2,300′) the mountain is seen to be flankt on both sides by benches (2,400′) which were mistaken in the distance for lava mesas, as they repeated the appearance of the well defined mountain-flank lava bench which borders the outwash plain hereabouts along its eastern border. A closer view showd the benches to be a mass of moraine and gravel, evidently reduced by lateral erosion from a former greater extent. To the northeast of Lone mountain, the washt scarp of the mesa is dotted with boulders, some of which are ten or fifteen feet in diameter. The surface of the mesa was found to be rolling, with low hills and shallow hollows. The arm of the mesa to the southwest of the mountain was not crost; but so far as could be judged it was there more like an outwash than a moraine deposit. The north slope of Lone mountain was strongly clift for 100 feet or more over its visible base, as if by ice scour or river undercutting.

The following suppositions may be made in connection with this high-level moraine and gravel mass. It has already been stated that the Kootenai-Flathead glacier has left two well markt moraines, separated by a distance of fifteen miles or more; the Bitterroot valley moraines, south of Missoula, also show a greater earlier, and a smaller later advance, as I saw during a brief visit in 1909. Hence the Kootenai- Flathead glacier probably had a similar two-fold advance. When this glacier first reacht the Pend Oreille district, the present lake trough was occupied by a valley of which the floor, as above shown, lay not much below the present lake surface. During the occupation of the valley by ice, it was deepend about 1,000 feet and its side slopes were scourd off into steep cliffs. Hence on the first coming of the glacier, the pathway through what is now the lake could not lead nearly so much of the ice stream as on the second coming; more of the first ice stream must therefore have turnd southwest, through the depressions between the isolated mountains. One of these earlier glacial arms may have past south along Hoodoo valley and built up the higher moraine and gravel mass in a large area around Lone mountain and beyond it; but when the Pend Oreille trough was deepend, a larger and larger part of the second glacial advance should have flowed through it, and the southwestern glacial arm must then

have been less extensiv. The increast ice-water outflow from the south end of the lake must finally have cut away all but the present Lone mountain remnants of the earlier and higher deposits.

Lake Coeur d'Alene.—The valleys that descend from the mountains to the outwash plain of the Pend Oreille glacier are bard, as several observers have noted, by the heavy deposits of outwasht gravel that stretch across their lower courses, and many of the valleys therefore hold lakes. The finest and largest example of the kind is Coeur d'Alene lake, which extends into the Coeur d'Alene mountains twenty miles south of the closed outlet at the mountain border, where a town of the same name lies, 28 miles east of Spokane. The gravel plain there has a height of 2,200 feet; Spokane river, the outlet of the lake, flows westward close along the mountain border on the south, as if pusht there by the aggradation of the outwash plain from the north. Seven miles west of the lake the river is superposed on the resistant rocks of a formerly buried mountain spur; down stream from the spur, the river course is more deeply incised in the gravels and its valley is well opend, as is usual in such cases. The river, divided into several streams, has cut as many small gorges across the rocky spur, and each gorge has falls at its head. The manufacturing village of Post Falls is there located. The graded course of the river up stream from the falls determins the present altitude of Lake Coeur d'Alene at 2,124 feet. The depth of the lake is said to be 400 feet not far from the outlet, and it is upon this record that a somewhat greater depth than 400 feet is inferd for the gravels in the middle of the outwash plain, as above noted.

Several branching valleys, now drownd in the arms of the lake, are enclosed by subdued mountains which rise to altitudes of 4,000 or 4,500 feet. Their slopes are often rimd with narrow lava benches at altitudes of from 2,300 to 2,500 feet. Hence, as already explaind, the lake arms represent valleys of two erosion periods, one before and one after the lava out-pouring; and it may now be added that the valleys have sufferd two drownings, long ago to a high level by the rising arms of the vast lava sea, now to a lower level by the ponded waters of the present lake. The two chief arms of the lake branch eastward from its southern point, and are enterd by rivers Coeur d'Alene and St. Joe, which come from the mountains of the Coeur d'Alene mining district farther east. The lake arms were originally some twenty miles long, but are now partly filld with delta flats.

The delta thru which the navigable waters of St. Joe River flow into the lake projects in two long, slender points, standing four or five feet above the river when I saw them, and sloping away on either side to marsh or lake level in a distance of two or three hundred feet, evi-

dently the results of turbid flood overflows. The points are tree lined near the river and grass-coverd farther back. A few miles above the delta points, the flats occupy the whole breadth of the drownd branch valleys; and there a number of secondary arms of the lake still remain as unfilld ponds; thus illustrating in a small way the origin of Lake Coeur d'Alene itself. The shore line of the present lake level is hardly modified by wave work; no shore lines were seen at higher levels; occasional low lava benches simulate abandond shore lines, but they are probably altogether of subaerial origin.

Other Lakes Enclosed by the Gravel Outwash.—Six other mountain valleys in this district are enclosed by the outwasht gravel plain so as to hold small lakes, and a few more hold marshes that were formerly small lakes. A small valley a mile to the east of the north end of Lake Coeur d'Alene is barred by the part of the outwash on which the town of Coeur d'Alene stands, and holds Fernan lake, about three miles in length, east to west, at an altitude of 2,129 feet. Six miles farther north, where the outwash plain stretches along the western flank of the mountains, which here reach heights of 5,000 feet, lies Hayden lake, the largest member of the smaller group, at an altitude of 2,242 feet. Its eastern shore has a number of drownd valley bays, somewhat shortend by deltas; most of its western shore is borderd by lava benches, a breach to the south of which indicates the probable former valley by which the trunk stream of half a dozen mountain branches made its escape to the plains.

The breach is now closed by the gravel plain at a height of nearly 2,300 feet; the resulting lake is about six miles in length from northeast to southwest. A shallow depression across the outwash plain to the southwest looks like the path of a former lake outlet; the lake water now escapes by percolation. When first known the lake was about four feet lower than now; a farmer who wisht to lower the lake a little more, so as to drain a swampy meadow at the former outlet, fired a blast where some of the water ran into the base of the lava slope on the south; but the blast obstructed the passage of escape and the lake rose four feet, killing the trees round its border and submerging several small baybars, apparently wave-built, but locally known as "beaver dams." Water is pumpt from the lake into irrigation canals for the gravel plain to the west.

If instead of going north from Lake Coeur d'Alene, we turn west along the northern border of the Mica Peak (5,250′) mountain mass, two obstructed valleys are found. The first is 15 miles east of Spokane and holds Liberty lake (2,052′), two miles long with a marshy delta at its head: it is reacht by electric railway from Spokane and serves as a pleasure resort. Two miles to the west, the valley of Saltese

creek has a marshy floor. Like Lake Coeur d'Alene, both these valleys have their outlets at the western side of the enclosing gravel deposits, as if pusht there by the aggrading gravels.

The mountain mass which culminates in Mt. Carlton (5,805′), 22 miles northeast of Spokane, and limits the outwash plain on the northwest, measures over twenty miles north and south, by about fifteen east and west. Four of its southeastern valleys contain lakes. The largest, known as Spirit lake (2,422′), Fig. 6, occupies four miles of the lower part of a valley that descends directly eastward from Mt. Carlton; the inflowing stream, Brickel creek, has formd a delta over a mile in length; the outlet, Spirit creek, turns north and then west between the Mt. Carlton mass and a smaller mass, with an unnamed summit (5,091′) on the north. The Spokane Chautauqua holds its meetings on the north side of the lake.

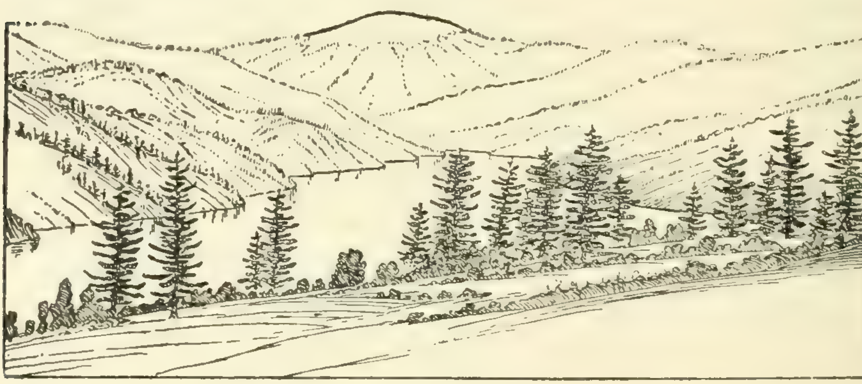

FIG. 6. Spirit Lake below Mount Carlton, looking East.

Three miles farther south, a similar valley holds Fisk lake (2,314′), nearly four miles in length; the outlet turns to the south along the mountain base, as if pusht there by the aggrading gravels. After passing two other small valleys, which seem to be enclosed as seen from the outside, and in the second of which the Rathdrum map shows a mile of marsh, one finds two other larger valleys in the southern flank of the mountain mass, holding Sucker (locally known as Hauser, 2,191′) and Newman (2,130′) lakes, one and two and a half miles long respectivly. The gravel benches stretching from spur to spur, back of which these lakes lie enclosed, look like artificial embankments when seen from a distance. They are narrow, because the broad channel excavated in the outwash gravel plain here has its border close to the mountain base. Indeed the northward widening of the broad channel seems to have been limited hereabouts by the rocky spurs, which end in steepend ledges or cliffs of small

height, worn back even with terraces cut in the gravels at one or more levels but often interrupted by outstanding, incompletely removed stacks.

All of these features, like the refresht lava scarps already mentiond, testify to the vigor of the ice-water river by which the broad channel was excavated in the gravel plain; but in this case the cut-back spur ends are, like the gravel-plain channel, the work of the clarified ice-water river in its later or degrading phase. The refresht lava scarps above mentiond on the eastern border of the highest outwasht gravels mark the work of the river in its earlier, aggrading phase. Between the cut-back spur ends above mentiond, the upper terrace scarp of the gravel bench is concave toward the broad channel in the outwash plain. This shows the work of the terracing river, sweeping laterally against the gravels as far as permitted by the resistant spurs, which were more slowly cut back. The slope of the gravel bench or embankment into the valley occupied by Newman lake has the form of delta-lobes, presumably built by small distributaries which flowd gently from the main aggrading ice-water river into this valley embayment. No traces of ice-action were seen in this district. Hence I doubt the correctness of the diagram facing page 144 of the Northern Pacific Route Guide Book (U. S. Geol. Surv., Bull. 611), in which a southwestern lobe of the ice sheet that bard Lake Missoula is represented as reaching Spokane. The morainic part of the Lone mountain mesa, described above, is the most advanced glacial deposit that I saw, and this is thirty miles northeast of Spokane.

If there ever were a lake enclosed in the valley of Latah creek, south of Spokane, it has been draind by the terracing stream, which has successfully re-opend its former valley. The valley of Little Spokane river also has no lake, presumably because of the deep entrenchment of the river in the outwash deposits. In this case it is probable that the broad gravel plain north of Spokane buries for some eight miles the former path of this tributary, for the Little Spokane now turns west just north of the gravel plain and makes its way by a much narrower passage between a lava mesa known as Five-mile prairie and a low mountain outpost north of it, to the main river.

The District Around Spokane.—The highest lava beds in the Spokane district stand at altitudes of about 2,500 feet. Their original continuity is now, as has been already stated, broadly interrupted hereabouts by the erosion of the open valleys of Spokane river and its branches. The uppermost beds are now seen only as comparativly narrow benches rimming the mountain flanks, or as partly or wholly isolated mesas, of which Pleasant prairie and Five-mile prairie, a few miles northeast and northwest of Spokane, are fine examples. These

two mesas have evidently taken their family name because of having a treeless upper surface: their escarpments, descending to lower levels in graded slopes which seldom exhibit bold outcrops, are usually wooded. The mesa surfaces or "prairies" have a deep and fertile soil, and are occupied by prosperous farms on which irrigation is unnecessary.

Farther west, where practically the whole country is occupied by lavas, the mountain outposts of the Spokane district are prolongd by lava-sheet spurs, as parts of a dissected plateau, but these spurs are at a lower level than the residual lava rims on the mountain slopes. The eastern border of the plateau two miles west of Spokane, along which a parkway road is in construction, offers a fine view of the several elements of the landscape here described. The deep valley of Spokane river, below the falls by which the location of the city is determind, is in the foreground, the river being 400 feet below the plateau rim; the subdued mountain group culminating in Mount Mica (5,250′) rises twenty miles to the east; another mountain group, culminating in Mt. Carlton (5,805′) also known as "Spokane mountain" and "Old Baldy," rises 22 miles to the northeast. besides some other smaller elevations of the same kind. Lava benches are seen discontinuously rimming the mountains, and lava mesas stand forth between them; finally in the distant background is the main body of the Coeur d'Alene mountains, south of Lake Pend Oreille, 35 or 40 miles away, beyond which a succession of mountains forms the great barrier between the East and the Far West.

Location of the City of Spokane.—Spokane is situated where the river of the same name, superposed on a lava bed while channeling the great gravel plain, cascades into what seems to be a re-excavated part of its preglacial valley. The location of the city close to the overlapping contact of the broad Columbia lava plateau with the western flank of the Rocky Mountains, gives it the advantageous variety of relations that is usually associated with natural boundary lines; and its position not far from the deep transverse valleys of Clark fork and Kootenai river through the mountains makes it a node of many converging railway lines, five of which have transcontinental rank. The important Coeur d'Alene mining district lies in the highlands to the east. The neighboring physiographic features are of varied interest: the superposed course of the river, as above noted, is one of them. Gravel terraces are well seen to the north of the city, the suburb of Lidgerwood standing on the higher one: also farther down the river valley,where they are associated with low-lying lava benches. Higher lava benches rise in the southern part of the city: there the recent development of a residential quarter has been skilfully pland

to accord with the form of the surface; the rigid scheme of squared streets which so often permanently disfigures a pleasing landscape for the short-lived convenience of dealers in rectangular lots, is here replaced by a system of gracefully curvd avenues, so sympathetic with the local relief as to enhance its beauty.

Steptoe Butte.—A brief digression may be here allowed to describe a fine example of an outlying mountain isolated in the lava plateau and known as Steptoe Butte, first reported by Russell.[17] It is fifty miles south of Spokane and ten miles west of the general mountain border, in that part of the plateau known as the Palouse country. There the surface is elaborately carvd into a relief of one or two hundred feet by the countless insequent branches of a mature or late-mature valley system, and deeply coverd with an impalpably fine soil, so that only the trunk valleys, sunk into the underlying lava beds with frequent outcropping ledges on their lower slopes, have running streams. The intricate contour lines of the Oakesdale quadrangle, United States Geological Survey, testify to the detail of dissection, but do not represent all of its minuteness. Steptoe butte is a treeless knob of quartzitic beds, which dip to the southwest; its summit rises 1,000 feet over the general surface of the plateau to an altitude of 3,613 feet. The hotel that stood on its summit at the time of Russell's visit has been burnd, and the road up the longer western slope is badly washt. The delicately sculptured surface of the plateau around the base and to the north, west and south is a vast expanse of rich farm lands, originally treeless tho small patches of trees are now growing near most of the farm houses; it was tinted at the time of my visit in three colors; the green of alfalfa, the yellow of harvested fields, and the neutral shade of plowd fallow land. To the west the horizon is unbroken; sixty miles to the south rises the broad low dome of the Blue mountains, a dissected uplift of the Columbia lavas, according to Russell; to the north a few low mountain outposts are seen; to the east beyond an intervening plateau belt of some ten miles, rise the subdued border ranges of the Rocky Mountain system, the transition from one province to the other being irregular but well markt.

Russell explaind the deep soil of the Palouse country as due to local weathering of the underlying lava. An alternative explanation ascribes it in large measure to dust brought by the prevailing winds from the drier part of the plateau farther west and caught here by the richer herbage, the growth of which is favord by the increasing

[17] I. C. Russell, Reconnaissance in Southeastern Washington, U. S. Geol. Surv., Water Supply . . . Papers, No. 4, 1897.

rainfall provoked by the approach of the winds to the mountains. Under both explanations, dissection must have gone on, chiefly by wash and creep, during accumulation. It is curious to note that the plateau farther north toward Spokane, where the climate is moist enough to support an open growth of pines, often has a thin, stony soil.

THE VALLEY OF UPPER CLARK FORK. *The valley for sixty miles above Lake Pend Oreille.* We may now turn to the valley of Upper Clark fork, the study of which was the prime object of my journey. Other districts have been described first, in order to make sure of the main element of the problem, namely, the upstream invasion of at least a part of Upper Clark fork valley by a distributary of the great Kootenai-Pend Oreille glacier. That there was some such invasion no doubt can remain, but its extent is undetermind. My censor judiciously urges that, as the other distributaries of the great glacier were not of extraordinary length, this southeastern one cannot have ascended Upper Clark fork valley very far. He therefore ascribes whatever ice erosion was done at points 50 or 100 miles distant from Lake Pend Oreille to an invading glacier or glaciers of more local origin, perhaps altogether detacht from and independent of the Pend Oreille distributary. The problems thus raised must be settled by an examination of the peculiar features of the valley, to which we now turn. The description will proceed up-stream, from northwest to southeast. It may be noted that the area over which marks of ice erosion are found is significantly greater than the glaciated area represented for this valley in the Northern Pacific Guide Book (diagram facing p. 144).

For the first 60 miles southeast of Lake Pend Oreille, the valley of Upper Clark fork has a width of from two to five miles; its floor is heavily covered with drift deposits which are frequently trenchd and terraced by the river; ledges occasionally rise thru the drift; the river is locally superposed on the rocks of the valley floor at one point, where it has cut a narrow cleft, known as Cabinet gorge. The valley sides in this long stretch were not well seen in my trips by train, but where they were visible, features which I noted as "scourd ledges and clift slopes" occurd. Other observers have, however, according to comments by the censor of this paper, found the side slopes in this stretch of the valley to be cloakd with residual soil; hence they exclude recent glacial erosion hereabouts.

The Thompson Falls Basin and Moraine.—At a point 60 miles southeast of Lake Pend Oreille, the valley of Upper Clark fork widens in a flat-floord basin measuring four of five miles across. The northwestern corner of the basin is occupied by a heavy morainic

mass a mile or two in width, on which I had a two-hour walk. Its rolling surface, sparsely dotted with boulders, rises from 200 to 350 feet over the basin floor next up stream. Glacial action at this point is unquestionable, altho the source of the glacier has not been determind surely. Its possible origin is suggested below. The river is turnd by the moraine to the southwestern side of the basin, where it is locally superposed on a strong valley-side spur, from which it cascades into a trench deeply incised in the drift and thus enters the lower sixty-mile stretch of its valley. The village of Thompson Falls lies near by. The Northern Pacific railway has a freight-line détour thru the drift trench for a number of miles, while its passenger trains follow a line on the broad drift bench. The Chicago, Milwaukee and St. Paul railway has constructed an electric power station at the falls, by which the trains of its mountain division are driven for several hundred miles.

The side slopes of the Thompson Falls basin have the moderate declivity and dissected form due to mature normal erosion. The aggraded basin floor (2,400′) is occupied by farms, and is borderd on the north by a number of low but well formd river terraces, some of which appear to be defended by boulder-set cusps of the moraine. The Northern Pacific railroad makes a gentle turn around one of the cusps a mile east of the station.

The Woodin-Weeksville Narrows.—The valley narrows about four miles east of Thompson Falls, and thereupon the walls become strongly clift and scourd, and so they continue for some 13 miles farther past Woodin, Eddy (2,437′) and Weeksville (2,453′) stations. On the northern side of the narrows near Eddy, the slopes of the normally rounded highland domes are cut back in bold cliffs, from which long talus slopes descend, continuously or interrupted by intermediate cliffs, to heavily scourd ledges near the level of the aggraded valley floor. On the southern side of the narrows, the cliffs truncate spurs and lateral valleys in the most impressive manner; large scourd and pluckt ledges interrupt the flat valley floor near the cliff base. These narrows would well repay more attentive study.

The Plains Basin.—The narrows are followed next up stream by an open basin, a few miles in diameter, with an aggraded floor on which a village has taken the appropriate name of Plains (2,482′): some low hills near by were interpreted as moraines; a higher bare hill, free from ledges and possibly a moraine like its lower neighbors, is delicately markt by seven or eight faint shore lines of Lake Missoula; these are the westernmost examples of their kind that I recognized. I had no means of determining whether the basin-like expansions of

the valley at and above Thompson Falls and at Plains are normally eroded excavations in areas of less resistant rocks, or small fault troughs, less uplifted than the adjoining highland masses; but the latter origin is confidently asserted for them in the Guidebook for the Northern Pacific Route (143). It may be at once noted that the Plains basin appears to offer an available path by which a glacier from the Cabinet mountains on the north may have reacht the valley of Upper Clark fork, and then flowd down valley as far as the Thompson Falls moraine and crept up valley to the farthest observd signs of valley-side scouring. This matter is further considerd in a later section.

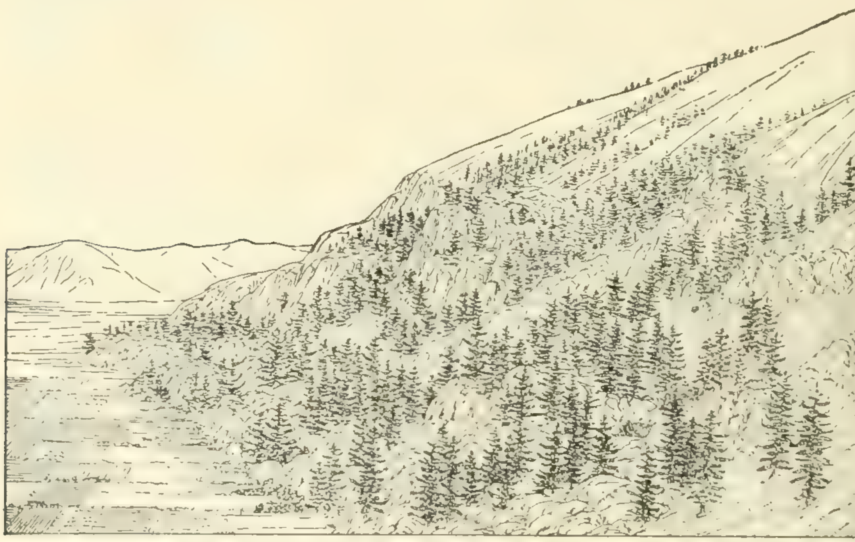

FIG. 7. Truncated spur in Clark Fork valley near Paradise, looking northwest.

The Paradise District.—The valley resumes its small width of a mile, more or less, with a flat, aggraded floor above the Plains basin, and here I spent three days with the small village of Paradise (2,499′) as headquarters. The sharp backhanded turn, by which Clark fork makes its way eastward from another southeast-northwest valley to receive Flathead river from the upper part of the valley thus far described, opens a mile above Paradise. Scourd and clift slopes at Paradise and in the Flathead section of the valley were seen for 22 miles above the Plains basin; they disappear near McDonald station (2,520′?). Similar scourd slopes were traced for several miles into the backhanded turn of Clark fork, as will be more fully stated below. The rocks hereabouts are quartzitic sandstones, similar to those seen in various other districts. Near Paradise, their

dip is steep to the southwest, but they are so uniformly resistant that the smaller valleys are of insequent habit, and all the hills and spurs are indifferent to rock structure. The highlands in which the valleys are incised were seen only from the valleys, but the distant skyline as seen in many views was so gently undulating as to warrant the description of the district as an uplifted, submaturely dissected peneplain. But it seems hardly warranted to describe the peneplain as having been "as flat as the prairies of North Dakota" (Guidebook, Northern Pacific Route, 153), unless prairies of strongly rolling form, not remarkable for their flatness, are intended.

The pronounced truncation of the valley-side spurs is strikingly exhibited in the view down stream from near Paradise, as represented in Fig. 7: the upper slopes are of moderate declivity, smooth and soil coverd, with every appearance of having resulted from long continued normal erosion; the lower slopes are steep and rugged, exhibiting many bare ledges, with every sign of vigorous scouring and plucking by glacial action, so recently extinct that the growing talus has not yet equalized the uneven descent. The lowest visible ledges pitch under the stratified drift of the valley floor, the total depth of which must be much greater than the 30 feet of gravel penetrated by a well near the station. The widend valley floor in the middle distance of Fig. 7 is part of the Plains basin: the beginning of the Weeksville-Eddy narrows is shown in the background at the left side of the figure. As was noted in the introductory pages, the details of this sketch and of several others in the same district must not be taken as exact; the ledges were not measured, the trees were not counted, nor were the valley-floor fields surveyed; nevertheless, trees and ledges and fields may serve, as here drawn, to suggest the character of the actual landscape.

Valley-Side Cliffs are not Fault Scarps.—It may perhaps be suggested that the valley-side cliffs, here ascribed to erosion by a valley glacier, are in reality due to faulting; but if so, the faulting must be of very recent date, much more recent than the basin faulting which is associated with the warping uplift of the mountainous highlands. For since the faulting of that epoch, the highlands have been submaturely dissected by small streams, whose valley sides are well opend and coverd with a graded sheet of creeping soil; while the valley-side cliffs here examind are of a much more modern date, for they undercut the graded slope of the highlands above them, and they still exhibit an abundance of bare rock, not yet reduced to moderate slopes by weathering. Again, if the cliffs are due to faulting, the faults must have a singularly close relation to the sides of a valley

of earlier origin; and this is inherently improbable. Moreover the cliffing and scouring of the valley sides weakens and disappears upstream, as described below, in a manner that is highly characteristic of the lessening work of a dwindling glacier, but not at all characteristic of faulting. Finally, the valley-side cliffs correspond closely with the spur-end cliffs already described along the margins of the Swan and Mission ranges in the Kootenai- Flathead depression. The explanation of the cliffs by faulting appears to me to be excluded.

It may perhaps be suggested that the valley-side cliffs are the product of revived river erosion, whereby a young and steep-sided valley was

FIG. 8. Moraine embankment in a side valley near Paradise, looking north.

incised beneath the graded slopes of a maturely open valley, as is the case for many miles in Frazer river valley of British Columbia, where it is followed by the Canadian Pacific railway. But it may be confidently urged that the present width of Clark fork valley is much too great for such an explanation. Furthermore the side cliffs sometimes truncate salients that enter the valley bends, where river erosion would be applied on the opposite or reentrant valley curve; a good example of this kind above Paradise is described in a later paragraph. Again, as shown in Figs. 10 and 11, the cliffs are often benched in a manner that seems beyond explanation by normal erosion on the side of a river-cut valley.

On the other hand, it may be objected that, if the cliffs are attributed to glacial erosion, striated rock surfaces, perched boulders, and morainic deposits should be associated with them; and none of these characteristic consequences of strong glacial erosion are conspicuous hereabouts. Indeed, perhaps because my search was hurried, I nowhere saw any glacial striations in Clark fork valley. The exposed ledges,

altho often well rounded, are so roughend by weathering as to have lost any striations that they may have once possesst. Yet I cannot doubt that if the drift and soil cover were removed, glacial striations would be found.

Moraines in Lateral Valleys.—Three side valleys not far below Paradise present independent evidence of glacial action in the form of transverse morainic embankments of small size, 400 or 500 feet above the main valley floor; one of them is sketched in Fig. 8, but as my point of view was on the valley floor, not far from the scourd base of the valley side, the figure does not give an adequate impression

Fig. 9. Scourd side of Clark Fork valley near Paradise, looking southwest.

of the height of the moraine. I walkt up to its crest and found it to lie somewhat back of the spur-end cliffs, with a steep slope toward the main valley and a gentle slope into the side valley, where a swampy hollow lay well below the embankment a quarter mile upstream. The slopes of the embankment were grasst over; no large boulders were seen; a few cobbles of crystalline rocks were found. I must dissent from the interpretation of these embankments as "deltas or terraces," marking "the mouths of small streams which at one time flowed into a lake whose surface was at the level of the terrace," as announced in the Guide book of the Northern Pacific Route (142); the back slope into the side-valley and the occurrence of crystalline cobbles suffices to exclude this explanation.

The view from the moraine across the main valley, too much schematized in Fig. 9, showd the southwestern valley side to be only moderately scourd, yet well enough to give a cascading quality to the lower course of some small streams where they descend from mature,

normal side ravines over ragged basal ledges. Stronger cliffs are seen farther up the main valley, on its northeastern side, as in Figs. 10 and 11. Here the interruption of the steepend descent by scourd ledges at intermediate heights was strongly developed. As before noted, such ledges would not characterize a valley deepend by river erosion alone; but they are expectable in a river valley that has been imperfectly scourd by an invading glacier.

FIG. 10. Scourd and bencht side of Clark Fork valley near Paradise, looking north.

A Truncated Salient above Paradise.—The most remarkable example of a completely truncated salient in the Paradise district, Fig. 12, is seen on the north side of the valley, about two miles upstream from the village, and almost opposit the entrance of Clark fork from its backhanded turn. The salient advances toward a concave reentrant in the other valley wall, and hence is as above noted, precisely in the position where the river could not truncate it. But a glacier, occupying the whole breadth of the valley and striving to reduce its bends, would exert a great scouring pressure on such a salient and would eventually cut it off whether the ice moved up stream or down stream. The truncation of this salient is similar to the demolition of the spurs in the meandering valley of the Dordogne in central France, where in the winter of 1898-99 I first realized how powerfully an invading glacier could remodel a previously eroded river valley. The spurs that normally project into the turns of the Dordogne valley are more or less completely destroyd in the upper part of the valley where it bears the marks of invasion by a local glacier that descended from the

volcanic mountain of the Cantal not far away; farther down stream the meandering valley retains its normal form.

The truncation of the Clark fork salient above Paradise, just considerd, as well as the truncation of other salients and the general steepening of the valley-side walls, should therefore be recognized as consistent with the observd effects of eroding glaciers elsewhere. Indeed all the evidence points to glacial erosion as the cause of these truncating valley-side cliffs. The clift face of the salient here in question is merely one of many spur-end cliffs in Upper Clark fork valley; it is more pronounced in its height of 400 or 500 feet than most of its neighbors, but it is exceeded in height and in length by the cliffs of the Woodin-Weeksville narrows.

Less emphatic marks of glacial scouring are seen on the upper slope of the salient just described, as well as on other salients and spurs, for one or two hundred feet above the top of the main cliffs; but apart from these subordinate, high-level roughnesses the mountain mass has a well subdued form with a smoothly graded, waste-coverd surface. Unfortunately the traveller by train is not allowd a good view of this impressive feature, as the Northern Pacific railway follows the base of the long talus slope, which for part of its spread is swept by the river; and altho the view from the train up the talus slope to the cliffs that tower above is impressive by itself, it lacks the suggestiv lesson given by the contrast between the abrupt and bare face of the cliffs and the rounded, waste-coverd slopes above them, as seen from the middle of the valley floor.

The Backhanded Turn of Clark Fork Valley.—The advance of a short branch of the invading glacier into the backhanded turn of the Clark fork valley near Paradise is another surprising feature of this district. It should be rememberd that Uppermost Clark fork, after pursuing an almost northwestward valley thru the mountains for about 100 miles—a stretch on which Deer Lodge, Missoula and St. Regis lie at the beginning, near-middle, and end—swings around nearly to the east and thus runs for about 12 miles, in the backhanded connecting valley, to the neighboring northwestward valley where it receives Flathead river from the eastsouthwest. There it resumes a northwestward course and so runs for nearly 90 miles to Lake Pend Oreille. Glacial scouring of valley-side spurs is traceable not only for some ten miles up the valley of Flathead river above its junction with Clark fork at the Paradise turn, but also for four or five miles into the backhanded turn of the Clark fork valley toward St. Regis. A railroad trip by a freight train from Paradise to St. Regis and farther up stream toward Missoula showd that the spurs of the valley side which faces northwest at the entrance to the turn, are severely

truncated in rugged forms for the first mile or more. Here the rocks are seen to dip steeply to the southwest. The many joints by which they are transected exercise much control at present on the details of the cliff-face forms, but the peculiar disposition of their oblique lines makes it impossible here, as on Kootenai lake, to believe that similar joints have exerted any controlling influence on the course of the branching valleys in the mountain sides above or beyond the area of glaciation. Farther up the turn (westward), the normal form of valley-side spurs is better preservd, altho they are still abundantly scourd and pluckt for three or four hundred feet above the river. Then for about two-thirds of the length of the turn, all

FIG. 11. Scourd and bencht side of Clark Fork valley near Paradise, looking northeast.

signs of glacial scouring vanish; the waste-coverd mountain salients are normally prolongd into the bends of the valley, which assumes so meandering a habit that the railway repeatedly bridges the river and tunnels the spurs in order to shorten its track. But whether the tunnels are in rock or in gravel I could not determine, as just here a series of unusually heavy drift terraces begins.

Upstream or southeast from St. Regis (2,647′) the valley of Uppermost Clark fork is more open; its side slopes are normally carvd, and occasionally show faint shoreline terraces where tree growth is wanting; stream terraces occupy the narrow valley bottom for fifty or one hundred feet over the river. At a number of points on this side-line excursion, views of the comparatively even skyline of the highlands were obtaind, which taken in connection with the steep dip of the rocks seem here as elsewhere to compel the interpretation of

the highland as an uplifted old-mountain region, probably deserving to be calld a peneplain, in which the valleys are the work of a later cycle of erosion.

Scourd Cliffs in Flathead Valley.—If we now return again to the main path of the Clark fork glacier and follow it up Flathead valley, which is locally narrowd for several miles, an abundance of glacially truncated, scourd, and torn spurs may be seen below the normal forms of the higher slopes for six or eight miles above Paradise; gulches are sometimes opend in the cliff faces transversely across the spurs, as if guided by master joints or faults. Four small

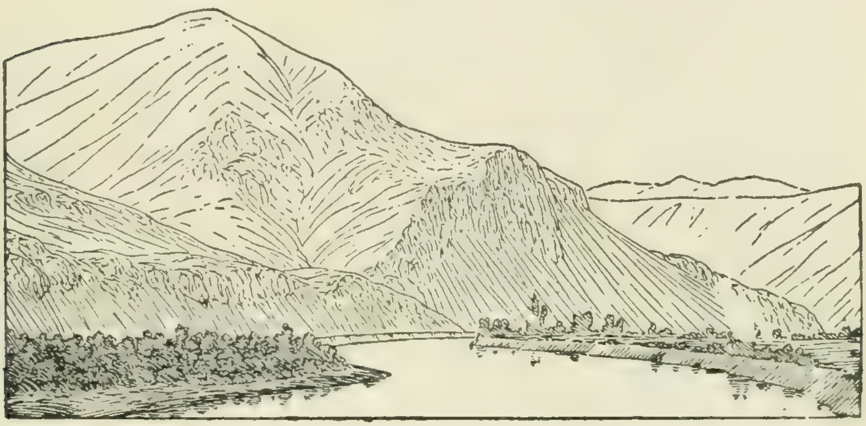

FIG. 12. A truncated salient in Clark Fork valley above Paradise, looking east.

embankments, believd to be moraines, were seen barring side valleys several hundred feet above the stream; one of them is notchd by its stream. The Guidebook of the Northern Pacific Route gives an empirical account of this part of the valley:—"The canyon is deep and narrow, and its walls are very precipitous . . . several diorite sills are conspicuously exposed. . . . The valley has high, rocky walls that rise 1,500 to 2,500 feet above the valley floor. The rocks are dark brownish red, but the large masses of broken rock below the cliffs are a much brighter red and give to the valley the appearance of being decorated with great red banners that are caught up at the base of the cliffs and stream down to the valley bottom in long, graceful curves. The walls are rugged and picturesque, but there is little or no variety, and one soon tires of watching the selfsame combination of river, talus slopes, and cliffs. The river, however, is really worth attention and presents many charming views of the clear water, almost turquoise blue, sweeping around willow-covered islands and between

the stately pines that dot the river's bank. . . . To the traveller interested in the geologic history of this region some of the most instructive features of this topography are small deltas or terraces in the side gulches at a height of fully 400 feet above the level of the track" (141, 142). I recognize fully the great value of the Railway Guidebooks as prepared by the Geological Survey, and recognize also that, at the present stage of geological investigation, a full knowledge of our vast Cordilleran region has not been gained—witness the interpretation here of side moraines as "deltas or terraces" already noted; but it may be suggested that observation of the "selfsame combination of river, talus slopes, and cliffs" will gain much interest to the traveller as soon as its meaning is pointed out: indeed, if the traveller is journeying eastward and watches understandingly the diminution and disappearance of the spur-end cliffs above Thompson Falls, and their replacement by subdued and waste-coverd valley-side forms of normal origin as he goes up the valley, the interest becomes absorbing.

Termination of Glacial Scouring.—A side stream, Camas creek, enters the main valley from the north by a narrow gorge, 13 miles above Paradise, and there lies the village embryo of Perma (2,511'); the creek drains part of an open treeless basin, a "camas" of the Indians, well occupied by farms; a large basin farther north but part of the same camas, with Camas for its chief town and a projected Camas canal in its irrigation scheme, is draind eastward by Little Bitterroot river which joins the Flathead some miles south of its lake. I had a general prospect over the Camas area from a fine lateral moraine, the largest example of its kind that I ascended, which forms a well defined embankment several hundred yards in length, and 500 or 600 feet above the stream, surmounting a low ridge of inclined and scourd ledges on the north side of the valley opposite Perma. Another embankment was noted on the upland about a mile to the north of the valley, suggesting a lateral extension of the valley glacier towards the Camas basin. The position and pattern of both these embankments seemd to me to preclude their having been formd by a glacier coming from the Camas basin on the north; they belong with scourd and clift spurs and salients of the valley sides as the work of a glacier that here ascended the valley and worked with decreasing intensity from Plains to this point and a little farther. Had the valley glacier been supplied from the Camas basin, its strongest erosiv work should be hereabouts, but that is not the case. Moreover, a waste-coverd spur sloping to the east, normally carved on rocks dipping to the west, was seen in profile beyond the farther one of the two embankments, and ript and notcht spurs were seen between the

two: hence the ice must have moved from the valley toward the Camas basin, as above stated.

On the south side of the valley at Perma the mountain side is scourd and ript, somewhat as in Fig. 13, but its slope is much less completely truncated than is usually the case near Paradise: curious channel-like chasms run irregularly along the ript slope, transverse to the spur-axis as if scourd out by ice along lines of weakness, or washt out by glacial-marginal streams. Ice-scouring is here the more probable process, because while the valley was occupied by the scouring glacier the valley sides should have been deeply submerged in Lake Missoula.

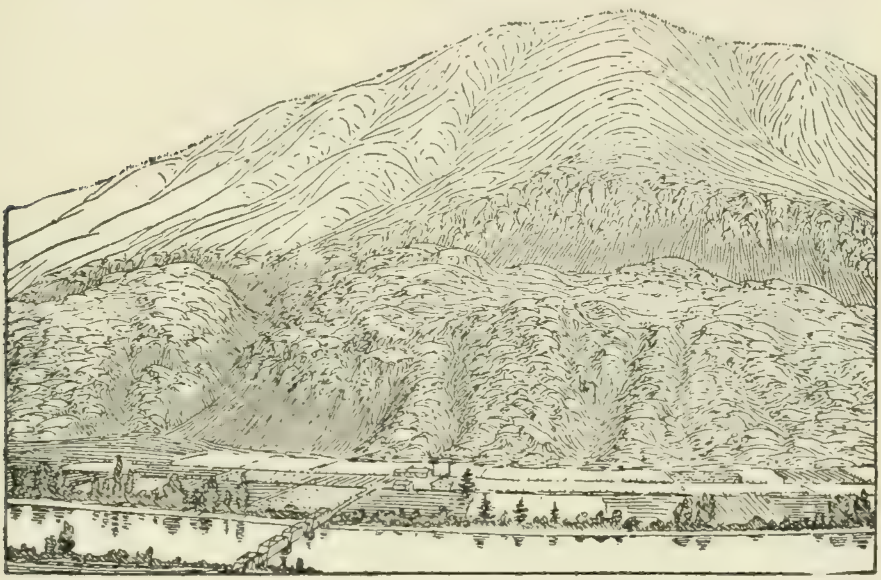

FIG. 13. Scourd and cleft mountain side at Perma, looking south.

A little farther east on the north side of the valley, a round hill about 500 feet in height, to the western slope of which the morainic embankment above mentiond is attacht, differs from the clift valley sides farther down stream in retaining a normal form, apparently little modified by glacial erosion; on the other hand it differs from the waste-coverd hills of normal form farther up stream, in exhibiting numerous outcrops of the nearly vertical strata of which it is composed. This hill is therefore interpreted as bearing the marks of light scouring by a glacier of small thickness, sufficient to remove most of the waste cover which such a hill should normally possess, but insufficient to destroy its general form. This is confirmd by finding that similar traces of glacial scouring on the lower slopes of

the valley sides continue for a few miles and that they gradually weaken and disappear six miles above Perma near McDonald station (2,518′).

Singular to relate, the limit of the glaciated section of the valley is not markt by any clearly defined terminal moraine: there are some large and softly molded hills in a valley-side embayment on the south near McDonald which may possibly be built of glacial deposits, but if so, their rounded forms suggest a much earlier origin than that of the small but well defined morainic embankments in the side valleys mentiond above. It is certainly remarkable that a glacier, of which the traces are seen in strongly clift valley sides farther down the valley, is not recorded here by abundant terminal deposits. Perhaps a reason for this may be found in the reduction of ice-pluckt blocks

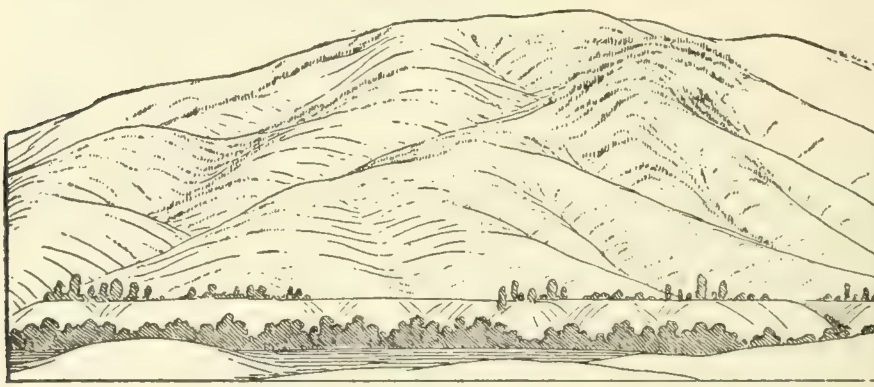

Fig. 14. Normal spurs and ravines at Dixon, near the junction of Jocko Creek and Flathead River, looking north

to fine sand and silt by long-distance scouring, and the removal of the sand and silt by sub-glacial down-valley currents. The vertical strata of the stript round hill seemd to be of slaty texture, and of less resistance than the quartzitic beds which form mountainous hills of greater height to the west. It is possible that the Camas depression on the north is to be ascribed, in part at least, to the more rapid erosion of the weaker slaty strata, which may there occupy a belt of greater breadth; but the manner in which the basin lies between the highlands, and especially the gentle declivity of the basin sides suggest that, like the larger depression which contains Flathead lake not many miles farther east, the Camas basin is chiefly due to the irregular down-warping—or failure of up-warping—of an old-mountain surface at the beginning of the current cycle of erosion rather than to erosion during the course of the cycle.

The Normal Valley of Jocko Creek.—After passing the last signs of light glacial scouring on the lower slopes of the valley sides

at McDonald, the railway ascends the valley 40 miles farther, and in this stretch, which is draind by Jocko creek above the entrance of Flathead river from the north, altho moderate variations of valley width occur, the valley sides show only normally carvd forms. Rock outcrops occur in the narrower gorges, but they are absent from the longer, maturely opend stretches. There the hills and spurs exhibit moderate variations of texture, shown in Figs. 14 and 15, but agree in possessing those smoothly graded slopes that are so significant of the long-continued action of the deliberate processes of weathering, creeping, and washing. A possible exception to this statement may be noted near Dixon where Flathead river comes in from the north. Here some hills rise on the south side of the valley like those above mentioned near McDonald, and may possibly be ancient moraines;

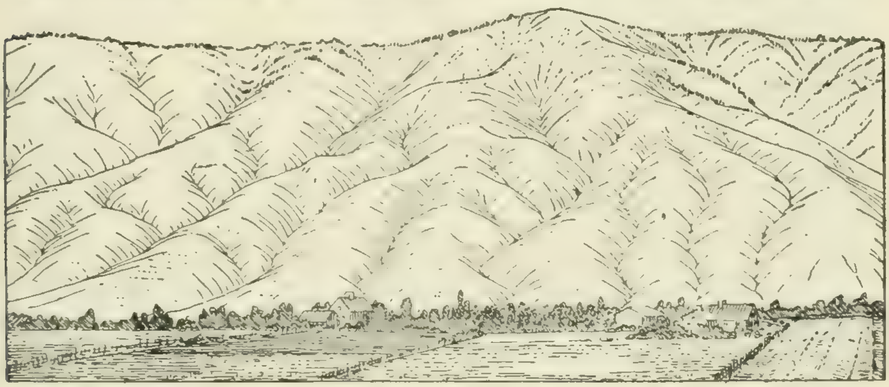

Fig. 15. Normal spurs and ravines in the valley of Jocko Creek at Arlee, looking north.

but if so, the glacial lobe that deposited them must be of even earlier date than the lobe which formd the Mission moraine, above mentiond.

The most significant feature of the normally subdued valley-sides is the perfect organization of their parts, whereby a delicate interdependence is establishd among all their many elements; this being an essential characteristic of a long establishd drainage system, as Gilbert first pointed out forty years ago in his classic report on the Henry mountains. Every element of the slopes is part of an elaborate system of down-hill lines, each of which begins in a convex profile above and descends to a concave profile below, and all of which unite in groups like the veins of a fern leaf along mid-rib lines, the mid-ribs in turn uniting in stronger lines, as in Fig. 15, and so on down to the main valley floor. The whole system of down-hill lines is developt in such a way as to dispose of creeping waste and running water in the most orderly fashion, so that their descent to the main valley shall be nowhere unduly retarded or hurried; and

all this evidently means the perfected accomplishment of a difficult task by the persistent, uninterrupted work of normal erosional processes, long continued without disturbance. When not alone the occurrence but also the meaning of these graceful forms is recognized, their increasing replacement by forms of an altogether different kind, as the valley is followd down stream, becomes impressively significant.

The heavy drift deposits in the valley of Upper Clark fork below Thompsons Falls have already been mentiond. From that point farther up stream, the valley floor is aggraded but the depth of its filling is not known as it is generally but little terraced, except in the backhanded turn near St. Regis. After the signs of glacial erosion are past at McDonald, the valley filling is trenchd to a depth of about 100 feet, and the terrace scarps thus formed consist of bedded silts, presumably of lacustrine origin; farther up stream, the trenching is less deep.

Source of Ice in Upper Clark Fork Valley.—The lateral cliffs in the valley of Upper Clark fork, above described as due to glacial erosion, may be reviewd with the object of discovering the possible sources of the glacier or glaciers by which the valley was invaded. It was suggested in the introduction to this essay that the invading glacier was a single, long, narrow distributary of the great Kootenai-Pend Oreille glacier, but the objections to such a single source presented by my censor seem valid and are here accepted; except that a short stretch of the valley up-stream from Pend Oreille lake was probably invaded by a distributary glacier thus supplied. A longer stretch of the valley for some thirty or forty miles above the probable end of this distributary has not been examind closely enough to determin surely whether it was glaciated or not: local glaciers from the Cabinet mountains may have reacht this stretch. The first indubitable signs of glacial action are found in the broad moraine that obstructs the valley by Thompson Falls, but the direction from which a glacier advanced to lay down this moraine was not learnd. No open entrance for a glacier from the north was here observd. Strong valley-side cliffs are found in the Woodin-Weeksville narrows between the Thompson Falls and the Plains basins; and again above the Plains basin in the Paradise district, beyond which their strength gradually decreases until all signs of glacial erosion disappear at McDonald in the Flathead extension of the Upper Clark fork valley. As the Thompson Falls basin seemd to be closed on the north, while the Plains basin is open for a considerable distance in that direction, it appears possible, as already briefly noted, that a glacier from the Cabinet mountains, advancing thru the Plains basin into Clark fork

valley, there brancht up and down stream and was responsible for the cliffing of the valley sides. After eroding strong cliffs in the narrows below Plains, the down-stream branch may have expanded so greatly in the Thompson Falls basin as to do little erosional work on the basin sides, altho it there, nearly twenty miles from its entrance, seems to have deposited a large moraine at the far end of the basin as the product of erosional work farther up its course. Similarly, an up-stream branch of an invading Plains glacier, after strongly cliffing the valley sides in the Paradise district and sending off a short back-handed branch toward St. Regis, gradually weakend toward Parma and disappeard at McDonald in the Flathead extension of the Upper Clark fork valley, nearly 20 miles above Plains.

There appears no possibility that an actively eroding glacier could have recently reacht the Paradise district from the upper Flathead or Jocko valley; first, because there are no lofty mountains near by to supply it; second, because the farthest recent advance of the great Kootenai-Flathead glacier into the Flathead basin did not reach nearly so far south as the Jocko valley; third, because the valleys in question bear no signs of recent glacial erosion above McDonald. The uppermost valleys of Clark fork, much farther east and south, were glaciated only near their heads. No ice could have possibly reached the Paradise district from those distant sources.

A stretch of country from the Plains basin northward to the Cabinet mountains probably contains the clue to the correct solution of the problem here outlined. A study of its glaciation would be repaying.

THE SHORE LINES OF LAKE MISSOULA. *General Features of the Shore Lines.*—The delicate horizontal benches that may be seen faintly contouring the smooth grassy slopes of many graded hills and mountains by which the basin of Upper Clark fork and its branches is enclosed, and that are particularly well shown on the mountain sides directly east of Missoula, north and south of the deep Clark fork notch, have been recognized as lake shore lines by many observers, but little has been publisht about the origin of their lake, to which the name of Lake Missoula has been given. The best description of the shore lines is by Pardee,[18] who gives also a summary of earlier observations and presents sound reasons for regarding the lake as bard by a heavy glacier which occupied Clarks fork valley near the north end of Lake Pend Oreille. A later general account of the Missoula shore lines and terraces is given in the Guidebook of the Northern Pacific Route: it closes with the statement:—"There seems to be a gradual decrease in the altitude of the terraces toward the northwest

[18] T. J. Pardee, The Glacial Lake Missoula, *Jour. Geol.*, XVIII, 1910, pp. 376-386.

that indicates a depression in the earth's crust in that direction since the beaches were formed, or a rise in the surface toward the southeast" (136). This opinion seems to me open to question, and it should remain so until exploration has been carried to much greater detail than it has yet reacht. None of the accounts of Lake Missoula make mention of the spur-end cliffs along the sides of Upper Clark fork valley as a result of erosion by the glacier that bard the lake.

The shore lines are so faintly markt that they are better seen at a distance of half a mile or more than near at hand. Instead of possessing nearly a vertical cliff rising at the back of a nearly horizontal bench, such as may be seen in the wave-cut shore lines of existing lakes, they show only a slight steepening and flattening of the soil-coverd slopes on which they are engraved. They are 10, 20 or 30 feet apart, and may sometimes be counted, one over the other, to the number of 20 or 25. They are by no means continuous; indeed it is surprising to note how arbitrarily they are distributed; for they are often imperceptible on bare rounded spurs, not far distant from smoother valley sides on which they are plainly visible. Where well developt, as on the northern slope of the subdued hills between the Flathead depression and the valley of Jocko creek, a down-hill line, tangent to the salients of the benches, would pass only from two to five feet outside of the reentrants. The visibility of the shore lines varies greatly with the relation of sunshine to the hillside aspect; they are said to be best seen after the partial melting of a light fall of snow. They never slant and branch after the manner of cattle tracks; it is their apparent horizontality and their exact parallelism when seen from a distance, that convinces the observer of their lacustrin origin.

The best series of shore lines that I examined by walking over them was on the northern slope of the subdued quartzite hills that form the southern boundary of the Flathead depression, separating it from the valley of Jocko creek. The position of the shore lines here made it manifest that the whole of the great depression, except so far as it was then occupied by the heavy ice of the Kootenai-Flathead glacier in the north, must have been deeply submerged in the lake waters. Occasional large erratic boulders, presumably ice-rafted to their present position, lie on these shore lines at various levels. In a notch in the hills, where a road passes from St. Ignatius to Ravalli on Jocko creek, a broad bar, Fig. 16, seems to have been formed by ice-rafted detritus.

Extent of Lake Missoula.—At the time of its greatest extent, when the surface of Lake Missoula reacht 4,200 feet altitude, it must have occupied a large area in the valleys of Upper Clark fork

and its branches, of which the chief are:—the broad Flathead basin on the north at least as far as the Polson moraine, the smaller Camas basin next west, and the valley of Jocko creek next south, the Bitterroot valley south of Missoula, the Blackfoot valley east of Missoula, and the short valley of St. Regis river west of the village of that name. The extreme length of this ramifying water body, from northwest to southeast, must have been over 150 miles. Its maximum depth at McDonald in the Flathead-Jocko extension of Upper Clark fork valley must have been 1,700 feet, as will be more fully shown below. A rough outline map of the lake is given in a figure opposit page 144 of the Guidebook to the Northern Pacific Route. Much detaild exploration will be necessary before the distribution of observable shore lines can be recorded, and until topograhic maps of all the region

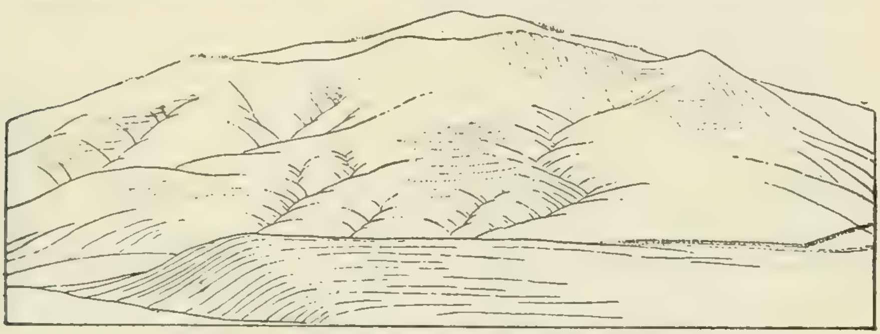

FIG. 16. Flat-floord notch near Ravalli, looking west.

concernd are publisht this exploration will probably not be undertaken; even then the detection of shore lines on forested slopes will be difficult if at all possible. On the other hand, the extent of the lake at its highest stage over all parts of the region where the altitude is less than about 4,200 feet cannot be doubted after the well defined shore lines at those altitudes near Missoula and elsewhere are recognized.

Section of a Shore Line.—Near the end of my excursion, I selected one of the best defined shore-line benches in the upper continuation of the Flathead-Clark fork valley, draind by Jocko creek, in which to have a trench cut so as to examin the bench structure. The locality of the cut is 15 miles southeast of the entrance of Flathead river from the north, on the southwest side of the valley near the village of Arlee on the Northern Pacific railway, where the hills are well graded in spite of their being composed of resistant quartzitic sandstones in inclined position. The trench was cut with proletariat aid to a length of about 15 feet and a depth of three or four feet; it disclosed a cover of brownish soil, with plentiful angular scraps of local sandstone

and occasional rounded stones of foreign origin; beneath this lay some two feet of well rounded cobbles, chiefly of local origin, coated with a gray calcareous incrustation. Unfortunately the time allowd for this work was too short to complete the trench down to bed rock and across the bench to its cliff, but the cutting sufficed to indicate that the benching of the slope had been originally much more distinct than it is now, and that creeping soil has largely obliterated the forms left by the waves. It would be well to have this conclusion confirmd by cuts in other benches.

The Lake Missoula Ice Barrier.—It may be reasonably inferd from these observations that Lake Missoula fluctuated in level without long remaining at any one height. The lake must be of late glacial or of postglacial date, because the shore lines are traceable on the southern or outer side of the great Polson moraine and on some of the piedmont moraines formed by local glaciers of the Mission range not far from St. Ignatius. Of these two dates the former is much more probable, because no postglacial barrier can be imagind to hold back the lake waters, while the well proved branch glacier which invaded Upper Clark fork valley next above Pend Oreille lake, or a glacier of more local origin farther up the valley, must have formd a barrier of satisfactory duration and strength. All the lakes of this region now overflow; hence in the cooler climate of the glacial period, Lake Missoula also must have overflowd. The fluctuation of lake level must therefore be interpreted as indicating a corresponding fluctuation in the height of the lake outlet; hence the outlet was probably across an ice barrier, or along the depression between the southward slope of an ice barrier and the northward slope of the adjoining mountains. A similar interpretation has been proposed for lakes recorded by faint shore lines at many levels in Scandinavia. The duration of the lake was longer than would be inferd at the first sight of its faint shore lines; for the benches were originally stronger than now. and they would have been stronger still if the country rock had not been so generally resistant and if the attack of the waves had not been distributed at many different levels. During the winters of the glacial period the lake was probably frozen over; during the summers, some of its bays and branches, especially those opening to the west, may have borne much floating ice; and both these conditions would have weakend wave work.

Probable Barrier and Outlet near Lake Pend Oreille.—Lake Missoula must have had its ice barrier and outlet either where the great Kootenai-Pend Oreille glacier abutted against the northern slopes of the mountain masses on which the southern distributaries of the

glacier were divided at the northern end of Lake Pend Oreille; or farther up Clark fork valley, probably near the Plains basin, where the valley seems to have been invaded by a local glacier from the Cabinet mountains. The first of the two locations seems the more probable because of the great thickness of the Kootenai-Pend Oreille glacier at that point. The barrier, if there, was probably on the eastern side of the lake, as Pardee has shown, for the mountain slope on that side of the lake basin, where the valley of Upper Clark fork joins it, is higher and steeper than on the western side. This location for the ice barrier is accepted in the U. S. Geological Survey Bulletin on the Northern Pacific Route (135). The ice must have been very thick here, for Calkins has traced marks of glaciation on the mountains a little farther north to a height of 2,500 feet above the lake, or 4,500 feet above sea level.

Further reasons for locating the ice barrier and outlet of Lake Missoula between this mountain slope and the abutting ice at the northeast end of Lake Pend Oreille are:—Even the lowest passes in the mountains at the distant headwaters of the Clark fork system, far to the east and south, are much higher than the level here reacht by the abutting ice. A northern escape for the lake waters must have been prevented by the great Kootenai-Flathead glacier which filld the depression between the Rocky Mountains and the Flathead-Cabinet mountains. The level at which the great Kootenai-Pend Oreille glacier abutted against the mountain mass between Clark fork valley and Lake Pend Oreille, as indicated by the upper limit of the oversteepend mountain-side slope, is between 4,000 and 4,500 feet, while the highest shore line is about 4,200 feet. Hence the outlet of the lake would seem to have followd the channel here defined by the southern slant of the ice surface against the northward slope of the mountain. Just as a southward distributary of the great glacier followd a valley which is now overdeepend in the trough of Lake Pend Oreille, so the southeastern distributary must have advanced a certain distance up the valley of Clark fork and overdeepend it; but this overdeepening is now counterbalanced by postglacial aggradation. How far it extended and to what degree it was accompanied by oversteepening of the valley sides remain to be determind.

It is unfortunate for my record that this location of the barrier was not defined during my excurison, for the base of the mountain concernd is only a mile from Clark Fork station of the Northern Pacific railway. The northern end of the mountain rises, according to the topographic map of the Priest Lake quadrangle, boldly in an oversteepend slope from the lake (2,051′) to an undulating crest in which the knobs range from 4,200 to 5,200 feet, and the notches from about 3,900 to 4,400 feet; two ravines a mile back of

the ridge open to the east and west; the lowest point in the divide between the ravines is about 4,200 feet, and to the south of this point the mountains soon rise above 6,000 feet. The divide at 4,200 feet is therefore a possible location for a short-lived highest overflow of Lake Missoula. During the rise and fall of the lake, its outlet must have been along the oversteepend slope of the northern ridge at many different levels. The sloping mountain side should therefore be searcht for bared, water-worn rock surfaces, associated with channels, potholes, and plunge-pools on salients at various levels, and adjoind by beds of boulders and gravels that may have been washt into the slopes of any reentrants.

Further signs of rushing waters should be lookt for on the mountain slopes that enclose Lake Pend Oreille on the east; they should be absent along the southeastern side of the basin where a small, independent proglacial lake must have occupied the normal, nonglacial valleys of the two Gold creeks that come from the Coeur d'Alene mountains; but they should begin again on the mountain slopes, beneath Bernard peak of Chilco mountain, that enclose the southwestern arm of Lake Pend Oreille on the south; except that here, as well as on the eastern side of the lake, the oversteepening of the mountain side by glacial erosion may have removed all traces of channels cut by the Lake Missoula outlet during the waxing phase of the glacial invasion; and that the walls thus oversteepend would not be well shaped for the erosion and preservation of outlet channels during the waning phase. The final discharge of the outlet must have been upon the great gravel plain that stretches from the moraine at the southwestern end of Lake Pend Oreille to Spokane and beyond: the discharge on the plain should be indicated by an abundance of boulders, brought from the ice or dislodged from the mountain side; the lake water here must have given helpful reenforcement to the sub-glacial waters that rose from beneath the Pend Oreille glacier; the latter were presumably well charged with detritus; the former must have been comparatively clear.

A Possible Lake Barrier in Upper Clark Fork Valley near Plains.—Altho the most probable location for the ice barrier of Lake Missoula appears to have been at the northeast end of Lake Pend Oreille, it is desirable to consider an alternative possibility; that of a barrier formd by a Cabinet-mountain glacier which filled the Plains basin and, abutting against the southern side of the Clark fork valley, sent out its inferd branches up and down stream. The altitude reacht by such a glacier is unknown; the relation of the time of its maximun advance to that of the much larger Kootenai-Pend Oreille glacier is undetermind. One may therefore conceive that, even if

the greater glacier for a time formd a lake barrier farther down Clark fork valley, the smaller glacier may have, earlier or later, formed an independent barrier at Plains. But the lake shore lines on the hills near Plains are manifestly against the possibility that the Plains ice barrier was of later date than the barrier farther down the valley; for when those shore lines were formd the Plains glacier must have withdrawn, altho the barrier farther down the valley was still present tho perhaps not at its highest level. If the Plains glacier withdrew from the Clark fork valley and the Plains basin sooner than the greater Kootenai-Pend Oreille glacier withdrew from the same valley farther down stream, then it is probable that the Plains glacier enterd the valley later than the greater glacier. Thus interpreted, its invasion of the valley was probably during the maximum stage of the greater glacier and therefore during the highest stage of the lake. Hence, unless the Plains glacier was strong enough to form a higher barrier than the one at Lake Pend Oreille and thus divide an upstream lake of greater altitude from a down-stream lake of less altitude, it must have been simply an invader of a continuous lake. Whether, as an invader, it crept along the lake bottom and was submerged beneath the lake surface, or whether it was floated up and more or less disintegrated by the lake waters, remains to be determind. This question will be examind in a later section.

The Deltas and Sediments of Lake Missoula.—As the Kootenai-Pend Oreille glacier advanced across the valley of Upper Clark fork, where that river reaches the northeastern arm of the present Pend Oreille lake, the river must have been displaced southward to the foot of the adjacent mountain; and thereupon Lake Missoula began to form. As the ice advanced farther and higher and its southern and southwestern arms were divided, the lake also rose higher, and thereupon deltas must have begun to form where the shortend course of Upper Clark fork enterd the lengthening lake; and as each delta advanced a little, all the valley floor farther upstream, as far as it had been previously graded, would then be aggraded. With still greater advance of the ice, as many of the lake deltas as were reacht and overridden by the branch glacier that entered Upper Clark fork near Lake Pend Oreille, or by a more local glacier farther up the valley, must have been scourd away; but beyond the farthest advance of the glacier the deltas might remain on the lake bottom, and merely suffer terracing after the lake fell and the river was reestablisht. The heavy terraces, which occupy part of the backhanded turn of Upper Clark fork valley below St. Regis, are probably of this origin; their coarse gravels must have been deposited either before or after a short branch glacier enterd the backhanded turn from its end

near Paradise at the time of greatest glacial advance, because when the ice was there the lake must have have been at its highest level, or over 4,000 feet altitude, and St. Regis would then have been submerged under 3,000 feet of lake water. On the other hand the delta which was formd by Upper Clark fork when the ice had its greatest advance ought to be as high as the highest lake shoreline and should therefore be searcht for much farther up the valley; the remnant of such a delta is probably to be found some 60 miles southeast of Missoula, a little distance above Gold Creek station (4,201′) of the Northern Pacific railway, where a long gravel terrace, about 40 feet over the river, was noted from a passing train. Similar terraces should be searched for in the Blackfoot and Bitterroot valleys.

The gravel of the St. Regis terraces should not be regarded as having been supplied by the outflow of water from an advancing branch glacier in the backhanded turn of Clark fork valley; first, because no similar gravels are found at the end of the glacier in the Flathead valley between Perma and Dixon; and second, because it is not likely that any concentrated stream ran out from the end of the glacier, for the glacier then terminated in the standing waters of Lake Missoula, and the discharge of the lake was 100 miles back of this ice end; hence there was probably no concentration of a discharging underflow stream beneath the ice, and no ice cave at the above noted glacier ends. The water melted from this part of the invading ice must have tended to find its way back toward the lake outlet. In view of the strength of the St. Regis terraces of Clark fork, it is curious that no similar terraces were formed by Flathead river, just below its elbow, when the lake stood at an altitude of about 2,600 feet; perhaps this is because the detritus from most of the Flathead headwaters was deposited in Flathead lake.

During the higher stands of Lake Missoula fine textured silts would be spread over the deeper parts of its bottom; they would be washt and trencht by extending streams as the lake fell. The gray silts now seen in many valley terraces, as at the outlet of Flathead lake by Polson and at the river elbow by Dixon, are apparently of this origin. The gravel that is strewn on some of the silt terraces probably represents river work as the lake was waning.

Disappearance of Lake Missoula.—During the fall of Lake Missoula, delta growth would take place on top of the lake silts at each pause, with corresponding aggradation of graded upstream stretches; and the whole series of deposits thus formd would tend to become confluent along the valley floor, or to be more or less terraced as the lake finally disappeard. Thus the valley of Upper Clark fork, for some miles below the backhanded turn where Flat-

head river joins it, has a flat floor; at Paradise, a mile below the turn, a well from which the railway water tower is supplied penetrated gravel for 30 feet without reaching rock. In the two basin-like expansions of the valley farther down stream, one at Plains, the other at Thompsons Falls, the valley floor is broadly aggraded and moderately terraced. Then for many miles down the valley, below the Thompsons Falls moraine, the valley floor is occupied by an aggraded gravel plain and the plain is trencht to depths of from 30 to 70 feet. Terraces are abundant here; rock knobs occasionally rise thru the terrace plain, and the river is sometimes locally superposed on nearly buried rock ledges, producing gorges and falls, as has been briefly stated on earlier pages.

Relation of Clark Fork Glaciers and Lake Missoula. *Assumed Synchronism of Glaciers and Lake.*—The conditions under which the side slopes of Upper Clark fork valley were scourd and clift remain to be examined. It has been made plain that, according to the best determination I could make on the ground, the scouring and cliffing were done by glacial ice; and that, adopting the suggestion of my censor, the ice presumably enterd the valley at more than one point in the form of several separate glaciers, after river erosion had given the valley a normal form essentially similar to that which it still exhibits in the non-glaciated headwater stretches. Now if the invading and eroding glaciers were synchronous with the great glacier that held up Lake Missoula at the head of Lake Pend Oreille, and therefore with the lake itself, it follows that the erosion of the valley-side cliffs must have been done at a considerable depth beneath the lake surface. In the Woodin-Weeksville narrows and in the Paradise district, the valley-side cliffs truly have a height of several hundred feet; but the aggraded valley floor over which they rise there stands at an altitude of only from 2,400 to 2,500 feet; while the highest lake shore line stands at 4,200 feet. Even if the region has been tilted since the lake disappeard, so that the highest shoreline hereabouts should stand at about 3,500 feet, the valley floor would have been at a depth of 1,000 feet in the lake waters. If no recent tilting has taken place and if the eroding glacier in this section of the valley really had its greatest size when the lake stood at its highest level, the base of the glacier on the rock bottom of the valley must have been about 2,000 feet below the lake surface; and the surface of the glacier near its up-stream end must have been under some 1,700 feet of lake water. This would certainly be a surprising relation of ice and water; yet the progress of the history of the problem of glacial erosion seems to give it some support, as the next paragraph will show.

Progress of Views on Glacial Erosion.—When the former existence of great valley glaciers in various mountain regions was first recognized over eighty years ago, the share that the glaciers had in eroding the valleys was not particularly considerd; indeed, at that time the origin of mountain valleys by erosion of any kind was not well assured. Some twenty-five years later, when Ramsay suggested that the piedmont lake basins of the Alps had been excavated by glaciers, he gave little or no attention to the erosional origin of the valleys upstream from the lakes. In the following years, when fiord valleys were attributed to glacial erosion by some daring theorists, it was more or less tacitly assumed that the erosion had been accomplisht while the land stood higher than now, and that the glacial troughs were invaded by sea water only after a postglacial subsidence. However, further consideration of this question led to the view that large glaciers might deepen their troughs somewhat below sea level; but that, the deeper their beds were eroded, the more their ice would be buoyed up by sea water, and the slower their further erosion would be. Gilbert went a step beyond when he pointed out that large glaciers press so heavily upon their beds that sea water may hardly find its way beneath them to buoy them up, and that they would therefore, even after excavating their troughs to a considerable depth beneath sea level, still press downward with their whole weight and continue their erosional work effectivly. Under this view, the depth to which a fiord glacier could erode its trough would depend chiefly upon a reduction of its velocity as a consequence of an increase in the cross-section of its trough, rather than upon its relation to sea level.

A final step in this progressive change of views would be taken if it should become necessary to recognize, in such cases as that of Clark fork, that glaciers may continue, even after they are wholly submerged, to erode the bed and sides of their troughs. There can be no question, however, that such a conclusion should be regarded as extremely doubtful until its acceptance is compelld by convincing evidence. Hence it is desirable to inquire particularly into the possibility of explaining the peculiar erosional features of Clark Fork valley in some other way than by the action of a submerged glacier.

The Lake Missoula Shore Lines may Antedate the Valley-side Cliffs.—The supposition that the valley-side cliffs of upper Clark Fork valley were eroded by a wholly submerged glacier is so inherently improbable and the mechanical difficulties that it involves as pointed out by my censor are so serious, that notwithstanding my acceptance of this supposition in a brief earlier essay,[19] an alter-

[19] Sublacustrine Glacial Erosion in Montana, *Proc. Nat. Acad. Sci.*, III, 1917, pp. 696-702.

nativ for it must now be examind; namely the possibility that the eroding glaciers of Clark Fork valley were not synchronous with the existence of the high-level stages of Lake Missoula.

It has already been stated that both of the great Canadian glaciers here considerd appear to have had epochs of farther extension markt by their more advanced moraines, and of less extension marked by less advanced moraines; and it is possible that these two epochs may have corresponded to the Illinoian and Wisconsin epochs of Glacial chronology. Let it now be supposed that while the Kootenai-Pend Oreille glacier made its greater advance and formd the heavy moraines at the southern end of Lake Pend Oreille, is servd, as already noted, as a high-level barrier across Upper Clark fork valley which was therefore filld with Lake Missoula. Let it be further supposed that the southeastern distributary of the Kootenai-Pend Oreille glacier was shortend by flotation in the deep lake waters so that it invaded Clark Fork valley for a relativly short distance. Also, that any glaciers which in that epoch reacht the lake from the Cabinet mountains were likewise broken up by flotation shortly after they enterd the lake waters and before they reacht Clark fork valley. Evidently the lateral cliffs of Clark fork valley could not have been eroded under these conditions. Farther east, in the Flathead basin, the Kootenai-Flathead glacier may have had thickness and weight enough not to be floated and broken up until it reacht the Mission moraine.

Now let the glacial conditions during the formation of the later moraines be considerd. In that epoch the Kootenai-Pend Oreille glacier is thought to have ended at the Elmira divide between the Clark fork and the Kootenai drainage basins. When it was thus situated, it would not have held back any lake in Upper Clark fork valley; and the local glaciers from the Cabinet mountains might then, not being broken up by flotation, have advanced farther than before, even tho glaciation in general was less severe. One or more such glaciers might under these conditions have reached Clark Fork valley where they would proceed to scour and cliff the side slopes in adapting the form of the valley to their needs.

So far as a right-hand or down-valley distributary of a possible Cabinet-mountains glaciers in Plains basin is concernd, no special difficulty arises regarding its erosion of cliffs in the Woodin-Weeksville narrows, for it need not have encounterd a lake there, unless one was formed by another Cabinet-mountain glacier farther west. But if the Plains glacier could send out a right-hand distributary several miles in length, it must have formd a strong barrier across Clark fork valley in the Plains district, and thus have held up a good-sized lake in the Paradise district and farther up stream: and the left-

hand distributary of the Plains glacier, by which it is here supposed that the cliffs of the Paradise district were scourd off, must have been more or less submerged in this lake. This would be particularly the case towards the up-stream extremity of the glacial distributary near Parma, where the valley floor is much below the top of the cliffs above Paradise, and hence much more below the barrier that the Plains glacier must have formd across the Clark fork valley. Hence while the suppositions here set forth diminish the difficulties that were encounterd in the preceding section, they do not dispose of them altogether. Some sublacustrin glacial erosion still seems to be demanded.

As complete escape from the necessity of assuming at least a certain amount of sublacustrine glacial erosion is not provided by the above suppositions, it is worth while to inquire into the possibility of a valley glacier holding itself in a valley bottom beneath the waters of an ice-barrier lake. If the ice front in such a lake were broad and free, the opportunity for its flotation would be increasd; but if only a narrow valley glacier is concernd, the manner in which it would wedge its way along the valley suggests that friction with the valley sides might seriously impede its flotation. The more the two valley sides were clift, the stronger would be the friction-hold on the ice between them. On the other hand, the presence of water above the ice would tend to counteract pressure from thicker ice in Plains valley, and thus to retard if not to prevent the advance of the ice-distributary up stream. As to this point, all I can say is, that if no lake had been there, the distributary might have had a greater length than the 20 miles from Plains to Parma. An up-valley advance for such a distance would be singular enough, even if no lake were present to impede it, but it would not be so forbiddingly extraordinary as an up-stream advance for 100 miles, as I had previously supposed to be necessary when the ice supply was assumed to come from the Kootenai-Pend Oreille glacier. Regarding the fact of an up-stream advance of 20 miles, that is no more than was accomplished by many an Alpine valley glacier as it emerged from a piedmont lake basin to its terminal moraine.

It will be a matter of interest to follow the results of future studies in this region, with special regard to the modifications that they demand in the views here set forth. In that connection it is desirable to state explicitly that the Plains glacier, to which reference has been repeatedly made on preceding pages, following the general suggestions of my censor, is at present altogether a hypothetical affair. Certification of its former existence would be gratifying; if proved, it might be well named after the anonymous prophet of its existence, if his name can be divulged by the Editor of the *Annals*. Other matters to which attention may be well directed are:—The indications of lake dis-

charge on the mountain slope that occupies the angle between Upper Clark fork valley and the trough of Lake Pend Oreille; the maximum height to which lake shore lines are found hereabouts and on the mountain sides to the southeast; the distance to which signs of glacial erosion are found in Upper Clark fork valley up stream from the lake; the nature of the Elmira divide between Clark fork and Kootenai drainage basins.

Annals of the Association of American Geographers
Volume X, pp. 149-152

MEMOIR OF FREDERICK VALENTINE EMERSON

ALBERT PERRY BRIGHAM

Our departed fellow worker and friend was born in Tillotson, Pennsylvania, in 1871 and he died in Baton Rouge, Louisiana, in October, 1919. Emerson was reared to farm life, but early developed his love of books and study. In the face of some difficulty, aided by the sympathy of a discerning mother, he entered upon a high school course. After a period of rural school teaching he pursued further studies in the normal school at Edinboro, Pennsylvania, where an acquaintance turned his interest toward Colgate University, from which he was graduated as a Bachelor of Arts in 1898. His modesty, earnestness and careful scholarship were, as in all later years, marked characteristics of his life in college. He elected no work in earth science until his Senior year began, but during that year he pursued all the courses that were open to him. He had intended to become a chemist, but a new interest seized his thought, stirred his imagination, and held him unwaveringly to the end of his life.

After graduation he engaged in high school teaching during a period of four years, at Warren, Steelton and Ardmore, Pennsylvania. As his interest grew and the way opened, he turned toward graduate study, becoming Assistant in Geology in Cornell University in 1903-1904, scholar in geology at Harvard University in 1904-1905, and fellow in geography and geology in the University of Chicago in 1905-1906. He received the degree of Doctor of Philosophy from the University of Chicago in 1907, his thesis dealing with the theme, "A Geographic Interpretation of New York City."

Professor J. Paul Goode writes that Dr. Emerson took the first degree in geography given in any American University. He was the only candidate for the degree in the department at Chicago at that time. Dr. Goode says further of him, "he was an ambitious student, with an insatiate appetite for work. He was enthusiastic in his conception of the great place the science should take in a liberal education and was anxious to contribute to the development of the field. He was courteous and sympathetic in his relations with others and the difficulties he overcame in getting his own education made him generous and helpful to the students who later in large numbers attended his classes."

During the summers of 1905 and 1906 he was an instructor in the summer school of the University of Missouri, a service which led to his appointment as instructor in geology in that institution in

the latter of those years. He had already had experience of summer school work in Cornell University, and had thus come into contact and sympathy with the work and needs of teachers of geography in the lower schools.

In going to the University of Missouri, his varied training in the earth sciences, his quiet but unquenchable enthusiasm and his experience as a teacher in secondary schools, added to teaching at Cornell and Chicago, all fitted him to enter fully into a large opportunity. Dr. C. F. Marbut, the head of his department in this period, says of him, "His chief characteristics, as I look back over his work while we were associated together were, patient, persistent, untiring effort, sustained by an absolutely unvarying devotion to his work. In his teaching he was thorough, never depending on unsupported generalities. He never entered his classroom without being fully prepared. He never undertook a piece of work without giving to it the best he had in him. He was conscientious almost to a fault."

In 1913, Dr. Emerson was made a member of the Sigma Xi fraternity by the chapter in the University of Missouri.

In 1913, Dr. Emerson was appointed Professor of Geology in the State University of Louisiana at Baton Rouge, in which he remained to the time of his death. Here he made a large place for himself, by the force of his scientific training, by his sincere, friendly and generous personality and by his unselfish devotion to the progress of his students.

I cannot otherwise so justly convey to the Association of American Geographers, the regard in which our late co-worker was held by his colleagues in Louisiana, as by quoting from a letter received from a fellow member of the University Faculty. "I never knew a more delightful man. He had a charming personality and everyone who knew him liked him. His students say that he was one of the best teachers on the faculty. They felt that he had a scholarly grasp of his subject and that he presented it in a remarkably clear and forceful manner. They realized too that he took a personal interest in them and in their work. He often had personal conferences with his students and they felt free to call upon him for help and advice at any time. I know of no one who was more genuinely loved by his students."

The Louisiana Faculty in its memorial action after Emerson's decease, recognize his fine qualities both as a man and a scholar, his innate modesty, his sympathetic qualities as a teacher, and his productive scholarship.

Throughout the period of his service in the University, he was connected also with the Experiment Station, and as head of the state soil survey he performed a large amount of field service and

issued several bulletins giving results of the work. He gave considerable effort in war service and spent much time at the beginning of the war in the writing of a report on road building materials for the Council of National Defense.

Dr. Emerson held his official titles and did much of his teaching and investigation in the field of geology, but his deepest interest seems always to have lain in the realm of human geography. He was through and through a geographer of the modern type, and his chief delight in his exact and thorough studies on the physical side of his science, was to trace the influence of these material factors upon the life and activities of man. This is evident through a glance at the titles in the subjoined bibliography.

Some of his geographic papers he read at meetings of the Association of American Geographers. He also published a very full and useful laboratory manual of physical geography which presents a vast body of serviceable help and suggestions drawn largely from studies of the topographic map of the United States.

He left at the time of his death, the manuscript of an important volume, bearing the title—"Agricultural Geology." This volume has now appeared and its publication gives satisfaction to all his friends and to all who are interested in this field of earth science. It was illustrated and put through the press by Mrs. Emerson in a manner which held true to all of its author's habit of careful scholarship and exacting thoroughness.

Professor Emerson's going carries with it the loss of a quarter of a century of geographic enrichment which might have been expected could his life have been prolonged.

He lived an ideal life in his home relations, the circle including his wife, a daughter and a son. Mrs. Emerson was a teacher before their marriage, and she was his intellectual companion, his critic and comrade in all his work. In his death our ranks are broken, in the loss of a gentle friend, a helper of young men, a tireless student, and a geographer who dwelt in the heart of the science and had vital convictions of its meaning and value.

BIBLIOGRAPHY OF F. V. EMERSON

The Shenandoah Valley in the Civil War, Jour. Sch. Geog., V, June 1901, pp. 208-214.

A Glimpse of the Steel Industry, Jour. Geog., II, Apr., 1903, pp. 169-178.

Physiographic Control of the Chattanooga Campaign, Pop. Sci. Mo., June, 1904, pp. 148-160; reprinted in Jour. Geog., IV, Feb., 1905, pp. 58-73.

Geographic Influences in the Atlanta Campaign, Jour. Geog., IV, Mar., 1905, pp. 106-121.

A Geographic Interpretation of New York City, Bull. Am. Geog. Soc., Oct., Dec., 1908, Jan., 1909, 57 pp.

Manual of Physical Geography, The Macmillan Co., 1909, pp. xvii+ 290.
Life Along a Graded River, Bull. Am. Geog. Soc., Sept., Oct., 1912, 16 pp.
Geography of Missouri, Univ. of Mo. Bull., Vol. I, No. 4, Dec., 1912.
The Geographic Story of Kaskaskia, Jour. Geog., VIII, May, 1910, pp. 193-201.
Some Geographic Responses in South Central Kansas, Bull. Geog. Soc. of Philadelphia, XI, Apr., 1913, pp. 41-50.
Geographic Influences in American Slavery, Bull. Am. Geog. Soc., XLIII, Jan., Feb., Mar., 1911, 37 pp. Series of historical maps in folded insert.
A Geographic Interpretation of Missouri, Geog. Jour. (London), Jan. and Feb., 1913, 30 pp.
A Colluvial Soil and Its People, Bull. Am. Geog. Soc., XLVI, No. 9, 1914, pp. 655-658.
Sour Soils and their Treatment, La. State Univ. and Agr. and Mech. Col., June, 1915.
Soils and Soil Types, La. State Univ. and Agr. and Mech. Col., Apr., 1916.
Geographic Influences in the Mississippi Valley, Miss. Val. Hist. Asso., Vol. VIII; also, La. State Univ. Bull., July, 1916.
Suggestions for Laboratory Work and Equipment in Physical Geography, La. State Univ. Bull., VIII, No. 9, Oct., 1916, 38 pp.
Loess-Depositing Winds in Louisiana, Jour. Geol., XXVI, No. 6, Sept.-Oct., 1918, pp. 532-541.
The Southern Long-Leaf Pine Belt, Geog. Rev., VII, Feb., 1919, pp. 81-90.
Agricultural Geology, John Wiley and Sons, pp. xviii+ 319, 270 illus., 1920.

TITLES AND ABSTRACTS OF PAPERS

St. Louis, 1919.

Charles Redway Dryer.

Presidential Address:—Genetic Geography; The Development of the Geographic Sense and Concept;—Printed in full herewith.

Isaiah Bowman.

Memorial of Theodore Roosevelt.

Albert P. Brigham

Memorial of Frederick V. Emerson;—Printed in full herewith.

Fred J. Breeze (Introduced by Charles R. Dryer.)

Southern Indiana;—A Regional Study.

The regional study of southern Indiana on which progress was reported is essentially a study of physiographic influence; or in other words, it is a quantitative study of the economic responses that man has made to the physical environment.

Southern Indiana includes the unglaciated portion of the state, the areas of Prewisconsin drift on each side of the unglaciated tract, and the margin of the area of Wisconsin drift border has been largely determined by geologic structure—A succession of thick series of hard and soft rocks, which dip gently to the southwest, gives rise to seven physiographic regions which trend roughly north and south. Each of these areas is different from the others in topography, soils, underlying bedrock, and other physiographic features. Because of the physiographic influences upon human economics, each of these belts is also a distinct economic region. These afford splendid opportunities for studies in geographic contrasts.

Stephen S. Visher (Introduced by Charles R. Dryer.)

Regional Geography of Southern Wyoming.

W. H. Haas (Introduced by H. H. Barrows.)

Physical Environment of the Cliff Dwellers of the Mesa Verde.

C. J. Posey (Introduced by R. H. Whitbeck.)

Regional Geography in Minneapolis—St. Paul.

The great northwest with its invigorating climate and with its resources of fields, forests, and mines furnishes an ample hinterland for the rise of a large urban center whose immediate location is determined by the falls in the great river which taps this hinterland. This site, moreover, is a natural focal point for present day lines of

commerce. The rapid and substantial growth of Minneapolis-St.Paul is, therefore, a true geographic expression of the development of the northwest.

J. Russell Smith.

A Proposed Division of North America into Economic Districts on Natural Regions—Read by Title.

Charles C. Colby (Introduced by H. H. Barrows.)

Commercial Divisions of the World.

Wellington D. Jones (Introduced by H. H. Barrows.)

Geographic Regions and their Subdivisions as Illustrated by China.

Ray. H. Whitbeck.

Geonomics.

Wm. M. Tucker (Introduced by Charles R. Dryer.)

The Geography of Columbus, Ohio.

W. W. Atwood.

Educational Advantages of the Regional Treatment of Geography.

Nevin M. Fenneman.

Geography as a Subject of Research.

An analysis of the nature of geographical research. The questions were raised:

What can the geographer do in the field aside from exploration, *i.e.*, what data should he gather first hand?

What kind of research problems await Geography in the case of a well known state like Missouri?

Albert P. Brigham.

Cape Cod and the Old Colony.

The region treated, which is essentially a natural region, includes Cape Cod and the eastward or shoreward parts of Plymouth County. The unity is shown to be physical, historical and industrial.

The physical basis was briefly described with outline of glacial history and topography and the maturing of the shore line.

The historical geography was dealt with by periods. Here we have the period of exploration and early settlement, including most of the seventeenth century; the period of colonial conditions, extending to

the close of the American Revolution; and the federal period. In all the periods the conditions of agriculture and marine activities were outlined.

In the federal period are included; the break up of marine interests at the close of the Revolution; the continuance of general agriculture and home industries; the vast growth of fishing, whaling and world-wide trade down to the Civil War; the decline after the Civil War and the new developments since 1870. The paper also considered, the limiting and localizing of fishing; the specializing of agriculture and manufacture; the development of transportation on sea and land, the changes in population; and the summer industry which is now, and will no doubt remain the dominant factor of subsistence and life in most of the region.

Carl O. Sauer (Introduced by H. H. Barrows.)

Economic Problems of the Ozark Highlands of Missouri.

Alexander G. Ruthven

The Geographic Factors in the Distribution of Animals, with particular reference to the distribution of the land Reptiles of the Davis Mountains Region, Texas. Read by title.

There are several objections to the life-zone theory of distribution which have not been met. The distribution of the land reptiles of the Davis Mountains Region, Texas, shows that the zonal distribution is less than would be expected on the life-zone theory and that there is evidence that other geographic factors than climate are to be recognized. It is suggested that the environmental relations should be considered a complex and that the geographic factors must be determined by ecological and physiological investigation.

Arthur G. Vestal (Introduced by H. C. Cowles.)

The Colorado Mountain Front; Subdivisions North of the Front Range.

The Laramie Range, an uplifted and almost undissected granite peneplain, has for its plant cover a dry grassland with sagebrush. The flat treeless condition continues to the Great Plains, in places without topographic or vegetational break even at the eastern front. Comparison with the Front Range shows that advancement to submature stage of present cycle is accomplished by greater diversity and luxuriance of vegetation.

The Poudre Foothills form the dry, moderately dissected eastern slope of the low mountains north of the Front Range. The outer and lower hills especially have scattered pines and the common shrubs only on upper slopes, with mountain mahogany (a ragged shrub)

on middle slopes. Dry grassland covers basal slopes as well as other slopes and upland flats which are much exposed to sun and wind.

THE POUDRE MOUNTAIN-FRONT, bordering the Poudre Foothills, is exceptional because of two synclinal folds forming embayments of sedimentary rock into the granite. Their relative weakness is responsible for local peneplanation in an early cycle, over their area and that of the adjoining granites. North of the folds there seem to be two mountain-fronts: the outer with cuestas bordering a moderately dissected granite scarp, and with woody foothill vegetation; then flat surface and plains short-grass over the local granite peneplain; then, six miles west of the outer front, a line of monadnocks, with another increase of elevation and again foothills vegetation. The broad northern part of the sedimentary zone bordering the granite is of low dip, giving butte and wide-spaced cuesta topography, with mountain mahogany dotting stony back-slopes and rocky infaces. Numbers of pinyons occur here locally, 130 miles north of their continuous range. Plains short-grass covers fine-soil surfaces of basal slopes, butte-tops, and open troughs between cuestas.

The southern part of the Poudre area has higher, submaturely dissected foothills, bordered by a narrowed sedimentary zone with cuesta-complex of high dip. Pine, mixed shrub, and the less xerophytic types of vegetation are developed almost as in the Front Range.

The writer believes that the details of floristic composition, successional development, relation to immediate ecological factors, and the classification of vegetation-types should find their place in systematic descriptions, which should precede regional description. The latter can thus be devoted to *actual occurrence in space* of the vegetation-types in relation to controlling physical features, and is thus *geographic,* rather than ecological, developmental, floristic, or concerned with classification.

N. A. Bengtson.

The Geographic Unity of Norway (Read by Title.)

Norway is usually referred to as part of Scandinavia and it is seldom thought of as having any right to be considered as a separate geographic province. Its racial and language relations with Sweden and Denmark have caused it to be considered as one of the Baltic countries. The trade changes brought about by war conditions have served to emphasize the fact that Norway is essentially an Atlantic facing country and that it holds an important gateway position for much north-European traffic. Its boundaries, resources, and commercial relations suggest a high degree of geographic unity, a fact which needs to be appreciated by American business if the best commercial interests of Norway and the United States are to be served.

G. E. Condra.
Geography of the Sandhills of Nebraska (Read by Title.)

Ray H. Whitbeck.
Geographic Influences of Lake Michigan on its Opposite Shores: Printed in full herewith.

F. E. Williams (Introduced by R. H. Whitbeck.)
Geographic Influences in Northern Minnesota—Read by Title.

Charles R. Dryer.
The Calumet District of Indiana—Read by Title.

George D. Hubbard and Orville C. Jones.
Some Basic Geographic Principles—Read by Title.

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THE PROBLEM OF LAND CLASSIFICATION

CARL O. SAUER

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STATEMENT OF GENERAL PROBLEM.—In regional geography there are two leading questions to be answered: To what uses is the area in question being put; and: What are its possibilities? On these two questions the fundamental technique of regional analysis rests. If these primary objects are expressed in the study of rural areas there will first be studies in the present utilization of the land and thereafter, some sort of land classification.

In the former, the present condition of the land is under scrutiny, as to kind of use, productive returns of each type of use, and the effectiveness of kind of production as related to type of land. In this manner the area may be broken up into smaller parts, each characterized by a distinctive system of production, and usually differing in returns as well. In so far as this type of study can be expressed by a map, the map will reproduce the landscape as a mosaic of differing economic practices, usually, though not necessarily, closely related to different types of land.[1] Corn farming may be carried on on land of very different qualities and may show returns of the most contrasted kind. It may represent the best use for the several kinds of land, or it may be out of place. Land utilization studies are concerned first of all with the facts of present production. They then attempt to discover the conditions favoring and handicapping present production. They thus lead up to the consideration of incomplete use and maladjustment in use.

Beyond this stage of the inquiry lies the problem of classifying the land according to its future utility. What incorrect uses can be remedied; what intensification of use may be expected? We are here

[1] See article "Mapping the Utilization of the Land," *Geographical Review*, vol. viii, 47-54.

dealing with expectation of highest and most permanent return. Development looks into the future. Our present land systems are the expression of economic experience to which sometimes must be added unintelligent habit. Much of our present practice is not based on permanent return but on immediate return, or exploitation. *We desire to know for our lands the expectations of most permanent return under most complete utilization. Land classification therefore is a qualitative grouping of the land, considering the land as a permanent resource under a normally developing economic system.* It is an attempt to reduce a program of land development to a critical basis rather than to the optimistic basis which it now usually has.

Purposes of Land Classification.—There are two immediate objects to land classification: 1) to determine most appropriate use, or, type of utility, and, 2) to discover what returns may be expected in comparison with other lands, or, relative value. The two purposes are measurably distinct; yet we are largely interested in type of utility in order to know values. If the term "land valuation" is employed in a broad sense, it is land valuation that land classification attempts. The prices paid for land constitute in effect a sort of land classification, for they express in one form the idea of expectation of return. It is entirely inadequate to think of land prices as based on income. They are a thing much more complex than the classical tradition regarding them.[2] But because they are the result of many forces other than the average expectation of their utility, land prices alone do not constitute an effective classification. It remains nevertheless a matter of keen regret that we do not have a comprehensive national service for the gathering of statistics of land prices, which would constitute a most important body of evidence.

Productive Equivalence, the Basis of Classification.—In a developed area, expectation of future return, it is true, is guided largely by the performance of the land to date, and land classification will make full use of available data on production. Thus there has been employed in Germany for many years a system of land classification, called Bonitierung. In this land is grouped according to normal yields of staple crops, as we speak of land that will grow a bale of cotton or fifty bushels of corn to the acre. It is worthy of note that in this system judgment of quality is based on the normal performance of the land rather than on the results which an individual producer secures. The emphasis is placed on the land, not on the skill of farming, an important consideration in the equitable assessment of taxes. In the case of undeveloped land this aid to rating quality is

[2] Aereboe, Die Beurteilung von Landgütern.

of course lacking entirely. It is precisely this latter type of land that in this country is in urgent need of a workable classification.

If, then, land is to be classified according to quality, the classification will be by a series of groups, ranging from highest expected return to none at all, either present or potential. *Each group will consist of lands of nearly equivalent returns, but not necessarily of similar type of use.* For the area in question the highest class will be that of the most productive and most generally desirable lands. A set of standards may be worked out for what shall be considered Class One lands in Illinois, or Michigan, or Massachusetts. These will of course not be equivalents for all three states. Standards may also be set for the country as a whole and the classification of an individual area will then be on the basis of this larger standard. It is evident that the larger the area the more difficult the formulation of a usable set of standards. The lowest class is the only one that presents no difficulty; it defines itself in terms of no productive value of the land. The intermediate classes are determined by reference to the top and bottom of the classification. Such a quality classification is not a soil classification, nor is it a crop classification. Under ths system neither the soil nor the crop appear in the designation of the class. The designation of quality is expressed simply by a series of numbers.

Geographic Factors in Classification.—Desirability of land is determined in the main by factors that are distinctly geographic. They are not such entirely. Credit facilities, current rates of interest, security of title, the burden of taxation, amount and character of labor supply, organization of markets affect land values strongly, without affecting estimation of the quality of land. Transportation conditions are covered only partly by geographic factors. It may be said that the quality of land is determined by appraisal of its physical character, but into market value the considerations mentioned above also enter. These latter are the expression of stage of development.

Just what place stage of development should hold in a land classification is undetermined. It is undergoing almost constant, often rapid, and sometimes abrupt change. Possibly it can be represented sufficiently by a record of land prices. The immediate objects of land classification do not need to consider this element. We need to know land quality now most urgently for the large tracts of land that are undeveloped and for those tracts that are passing out of use. No one knows the extent of idle land in the country. The best-informed person in the South estimates the amount of idle land in that section at three hundred millions of acres.[3] The majority of this is cut-over land. In the Great Lakes states there are approximately forty million

[3] Ucker, in *Miss. Valley Mag.*, vol. II, no. 7, p. 10.

acres of cut-over and swamp lands. These are the lands for which a policy of use is needed and it is here that land classification encounters its great present-day problem.

If stage of development is disregarded, the productive value of land is expressed by the sum of the environmental conditions. These are: 1) the crop characteristics of the climate; especially length of growing season, distribution of sunshine and warmth through the growing season; likelihood of unseasonable frosts; amount of evaporation; amount, seasonal distribution, and variability of rainfall; snow cover; moisture stored over winter, and frequency of destructive storms; 2) soil characteristics with reference to the elements of fertility; ease of working; ground temperatures, and movement of soil water; 3) surface conditions; as to slope, relief, exposure (including local modifications of climate), and drainage; 4) water supply; 5) sizes of areas presenting uniform characteristics; 6) location in the economic and social sense, as affecting problems of production and residential desirability; and 7) the plant and animal environment. To the last item belong many considerations, only a few of which may be stated here. Stumps have constituted one of the greatest problems in American farm development. In the northern states pine stumps, especially white pine, remain a most serious obstacle to land clearing for many, many years. There is known as yet no generally profitable way for the removal of the stumps of a number of our conifers, and their resinous qualities make them proof against decay for long periods of years. Such lands present a difficult problem of use. Native, or introduced, plants and animals may compete so successfully with crops, or they may prey upon crops or stock, or they may affect health in such a manner, as to reduce seriously the desirability of farm lands, forest sites, or ranching, although the other conditions of the physical environment may be altogether favorable.

If these things must be taken into account in a land classification, the classification will need revision from time to time. It is one of the fundamental ideas of geography that the values of an environment are subject to change. One can hardly hope for a permanent classification. The significance of a body of land may be changed by soil erosion, by drainage or irrigation, by improved markets, by fire, by introduction of pests or the conquest of plant or animal enemies, and in many other ways. The economic situation in general may change through the demand for new types of products or the general depletion of others, as illustrated in the increasing value of timber lands. No land classification should attempt to forecast permanent optimum use of land, and in many cases it cannot fix permanently the quality class to which land is assigned. Its purpose is to work out a rational basis of development for a generation or two.

System of Classes.—Readjustments of classification will be reduced principally in two ways, by paying least attention to the most changeable factors, and by keeping the number of quality classes at the minimum. The German Bonitierung recognizes eight classes. The classification here proposed suggests seven.[4] All agricultural lands are put in classes One to Four, forest and grazing lands in classes Three to Six, and waste lands may occupy classes Six and Seven. It is assumed therefore that there may exist several uses for lands of the same quality class, and that the same body of land may have several equally good uses. In lands of intermediate grade agriculture has no exclusive claim. It is only in the upper grades that agriculture represents the highest use without question. Agriculture in itself is not the highest productive use of land; it is such only for certain lands.[5] There are farm lands at the margin of profitable return and lands below that margin. There are moreover agricultural lands above the agricultural margin that may be more profitably employed in other ways. Forest and grazing lands may not only be competitors on even terms, they may have a distinctly superior position with reference to farming. This classification therefore establishes *an overlapping stratification of use on the basis of economic equivalence.* In many cases there exists in practice a mixed use by farming, forest growth, and grazing, because the returns from one use do not show a clearly greater return than is secured from the others. In other cases one use is exchanged for another according to the temporary economic situation.[6]

Class One.—In Class One all conditions are highly favorable. Returns are to be expected at the highest level and there should be every possible assurance of the maintenance of returns at the maximum level. This is permanently first quality land. From the investment standpoint it will represent the most gilt-edged of all investments, representing a type of land that even neglect and abuse cannot ruin. It should have a climate and soil suited in superior measure to the growth of the most profitable and important staples of agriculture. In our interior states it is most commonly corn and clover land, or it grows sugar beets, tobacco, flax, or alfalfa as the dominant crop. It should grow a number of important staples well, including one of the better legumes, so that returns may be kept at the highest mark should the demand for one crop fall off. It must be adapted to successful crop rotation, and to live stock farming, by way of insurance of permanent fertility.

[4] See scheme of classification accompanying this paper (p. 12). See also Ricardo, Principles of Political Economy, on Rent.

[5] Roth, Forest Valuation, 135-141.

[6] The terms "agriculture" and "crops" are used in this paper in their restricted sense.

These requisites demand 1) a reasonably long growing season, freedom from drought and excessively wet weather in so far as both demands can be met by one climate, adequate moisture during the period of most active growth, and sunny weather for ripening the crop. 2) A strong and balanced soil is demanded, carrying an abundance of plant food with good lime content, and of good behavior in times of dry as well as wet weather. 3) Good drainage and freedom from destructive floods, and also safety from slope wash are demanded. 4) An adequate water supply for all farming needs must be assured. 5) The land should lie in large and compact bodies, so that it may develop adequate centers for its commercial needs and an ample social life. How large an area is needed in American rural districts to have sufficient market facilities and social development is not known, for relation of size of area to character of development has not as yet been made the object of inquiry. It seems that at least a township of productive land is required for a good rural community. The township high school is the very smallest unit of secondary education that has been able to maintain itself, and then only if there is an exceptionally large population. Consolidated schools may approximate the limits of a township in the size of their district. In many agricultural sections a township of land is not enough for the development of a good market town. It is generally possible to determine that land values are reduced because of poor markets and social handicaps, where there is a small, detached body of good soil. Good land in small tracts is very rarely as desirable as the same type of land in large compact bodies. 6) The economic location must be such that access to the great markets outside is satisfactory. 7) Finally there should be no serious problem to production arising from plant or animal pests. The result is Class One A, the ideal farming country, the standard to which other lands are referred. For the country at large the highest type is the heart of the corn belt.

Climate, soil, and drainage are the most important considerations of quality. They may be fully satisfactory, but the land may be deficient in regard to one of the other conditions, which may be called minor. The body of land may be undersized. The market problem may present permanent difficulties, as is the case usually where a great distance separates producing and consuming districts. If this deficiency is of the minor rather than the major order, the land belongs to a modified Class One and may be designated as One B.

By definition, Class One is to be land highly productive of several important crops and is to show the greatest security of return. There are areas in which some specialized product is grown with profits comparable to those of the highest farming of Class One, on soil that has little value for general farming. This situation is to be found especially in a number of our fruit and gardening sections. Where

an important region of this sort is fully established it may form a further sub-class (One-X). In such a case however achievement alone, not expectation, determines the classification, and the greatest caution is indicated. If the success is due simply to skillful individual management, the situation is entirely beyond the scope of land classification. If the industry in question has become so well established through market organization, or otherwise, that a highly positive advantage is derived from the mere fact of ownership of land in that locality, then a superior economic location is to be recorded. The proper attitude in examining such a condition may well be decidedly one of scepticism.

These successful specialized districts, usually horticultural in character, derive their importance ordinarily from a superior shipping location, or a peculiar condition of local climate, together with a proven organization of skilled producers. The soil is a very minor factor in most cases, the intensive tillage employed and the advantage of early maturity simply indicating lighter textured soils as more desirable. At this particular point there belongs a danger signal. The fact that land will grow strawberries successfully does not cause it to sell at the price of strawberry land and does not entitle it to advanced rating. We have tens of millions of acres that could be used for various types of garden production in so far as soil conditions are concerned, but which have no likelihood of such use. One of the greatest wrongs perpetrated in real estate operations is the sale of light lands on the basis of such intensive production. The capitalization of these lands at fancy figures is on the fictitious basis of the performance of successful truck growing districts on similar soil. Yet the similarity of the soil is the least important consideration. In view of the enormous surplus areas of lands of light texture the promotion of such a tract does not change its low intrinsic value. Even a highly successful trucking district is not to be considered coordinate with the best general farming regions because its position is less secure. The organization of growers may break down; increased transportation costs may cause the profits of the industry to disappear; a plant disease may appear that destroys the crop. If anything happens to cause the successful crop to lose some of its profitable character in any particular location the value of the district may be lost. It is not so with land that grows many things well. For this reason the necessity of alternative staple crops is emphasized for strictly first-class land.

Excepting One-X, land that is now first-class should give every assurance of remaining such, if it is to be rated as Class One. Lands of lower classification may be moved up into Class One under certain circumstances, as through drainage or irrigation. In such cases however the accomplished improvement is necessary. The best expectations

of drainage of a swamp or the irrigation of a desert leave the value of the tract still speculative. There are numerous illustrations of partial disappointment in most carefully planned reclamation projects. Demonstrated success alone can force favorable revision of the classification.

Class Two.—Class Two includes land less profitable than Class One, but still satisfactory farm land and distinctly better suited to farming use than to grazing or timber growing. Climatic conditions may be less favorable, as in our wheat belt, or the soil may be less productive. Here belong most of the heavy clays and the lighter loams, as well as soils of deficient or excessive organic content. Care in handling may be necessary to prevent soil erosion. The class will be determined largely by the elimination of Class One and the determination of the upper limits of Class Three. It is in this area that the majority of the farm land of southern Michigan lies, and probably as well the majority of farms the country over. It represents the reasonably good farming country, and, in its lower parts, the land that is only fair. It may be subdivided into two classes. The upper division will include for our interior states the typical wheat, barley, and oats land, the lower division the major areas planted to rye, potatoes, beans, and common hay. In this class there may be minor areas of non-arable surface, increasing in amount toward the lower limit of the class. With decreasing productive possibilities, hillsides and sandy or rocky patches may become more numerous. Unevenness of surface causes land of good soil and climatic conditions to go into this class. Where roughness of topography is a factor, fields tend to be smaller and more irregular in outline than in the superior group of lands, labor costs are higher, machine farming is less prominent, and operations in general are on a smaller scale. In the older farming districts of second grade land the use of artificial fertilizers is common if cash crops are grown. Under reasonable care however the permanence of farming use should be assured for all land in this group. If as the result of abuse, soil erosion or sand blows set in, or the land deteriorates in some other way, it is dropped down at least one class. Since very different causes may determine the placing of land in Class Two we may find it in very dissimilar areas: The small grain districts of the western part of our interior, the farms of the northern glaciated areas, the old soils of the South, the better farms of hill sections, mostly, through handicap of climate or soil or location, have their highest possible place in Class Two.

Class Three.—In Class Three agriculture no longer has unqualified prior claim to the land. Here belongs in the first place the marginal

farming land. It may be land from which a farmer of superior skill and energy can produce satisfactory returns, but on which the average farmer will do well in exceptional years only and in ordinary years will barely worry a living out of his farm. This land, in the long run, may give approximately as good returns under forest or grazing use. There is no definite highest use of the land determined, except as conditions of time and person determine it. The land may be best used now as farm land; a few years ago it may have yielded most as pasture; and in the near future may be given over to the growing of forests, or *vice versa*. In short, agricultural use, where present, does not enjoy the permanence of the higher classes. Northern Michigan has many farms of this class which are well worked, partially worked, or temporarily abandoned, according to the changing labor conditions that exist in the factories and mines.

The percentage of arable surface may be so low that a combined economy with grazing or wood cutting is imposed upon the owner of the land. In this case the fields are not sufficient to support the farm. Into these two divisions fall the lands on the dry margins of the country that are semipermanently farmed, the regions of summer frost damage, the lands on which continued cultivation makes ever more difficult the problem of maintaining soil fertility, and the areas in which continued cropping carries the threat of serious soil wash. In the eastern half of the United States probably the majority of the sandy lands, now farmed, belong in this class.

The class may also be thought of as embracing the lands for which there is good hope of drainage or irrigation, but not as yet reclaimed. It should embrace all those lands that may be farmed, but about which there is some doubt of their permanent use for farming. Here belong also the high grade forest and grazing lands, not only such tracts as may be converted to any one of the three productive uses of land, but also those that are good only for forests or for grass. It should contain the absolute grazing lands of good quality in the dryer and colder sections. It will contain also absolute forest land, of superior quality of site, in mountain and hill sections.

In summary, in this class agriculture, forestry, and grazing meet on fairly even terms for certain groups of land. Others belong exclusively to the ranch or the forest. Ideally, the average returns from any one use should approximate those from either of the other uses. *Where land of this class is undeveloped at present, it should not be recommended for agricultural development.* We have better lands, in large amounts, available in the superior classes. As long as that condition exists, it is an economic error to start farming on a basis of meagre return. For the present such lands should have the opportunity to grow at least one crop of timber.

SCHEME OF LAND CLASSIFICATION

Class	Agriculture	Grazing	Forest	Nonproductive
IA	Permanently best cropland; can withstand abuse. Suitable for variety of staple crops. Approximates ideal conditions.	Only incidental or temporary.	Only incidental or temporary.	Not permanently.
IB	Minor deficiency, as small size, deficient location.	do.	do.	do.
IX	Highly successful specialized farming, without breadth of resources of IA.	do.	do.	do.
IIA	Good agricultural land with satisfactory returns. Includes especially the major small grain lands.	Incidental to crop-farming.	do.	Very minor tracts of land not suited to production may be included.
IIB	Fair land, yielding sufficient returns so that it is occupied continuously for farming purposes. Especially small farming type.	do.	do.	
III	A) Marginal agriculture. B) Agricultural value probable but not proven. C) Land economy rests on necessity of farming joined with grazing, or forests, or both.	High grade.	High grade.	Minor areas of nonproductive land may be present.
IV	A) Submarginal farming. B) Any continued farming is destructive of the land.	Second grade.	Second grade.	do.
V	None.	Low grade, but commercially significant.	Low grade but commercially significant.	Waste land may form an important part of land area.
VI	None.	Emergency range.	Protective forests.	do.
VII	None.	None.	None.	All.

Class Four.—Agriculture in Class Four is out of place. Where carried on, it represents pauper farming or else a destructive use of the land. In the past few years tobacco has been grown with good immediate profits on rough limestone hills, but with the result that the clean cultivation of this crop has caused the soil to be eroded rapidly. Many of these old tobacco fields have been converted into sheep pastures. Cotton and corn are doing the same thing on many southern hillside farms. Where field cultivation destroys the land, agriculture is evidently out of place, and the land should be placed in a class below those that are agricultural. Where the returns of farming are persistently submarginal the land also falls into this class. We have in this country a fairly large agricultural population, so-called, that relies for a large part of its support on outside labor. Farm income studies in Michigan show a surprisingly large reliance on outside sources by the farmers living on the poorer lands of the northern part of the state. A variation of this condition is found in certain sections of the south, where standards of living are incredibly low, and in many cases still shrinking. Both of these groups constitute in effect pauper farming. To Class Four belongs the bulk of the country that should be our permanent forest and grazing land, now largely represented by cut-over lands and by our semi-arid regions.

Class Five.—Class Five represents low grade grazing and forest lands. The grazing lands furnish sheep rather than cattle pasture. The timber lands are occupied by trees of slow growth and often of low grade. These are the marginal areas for commercial grazing and timber production and are the result of rather unfavorable conditions of climate, soil, slope, drainage, and location. Michigan has this condition in her poor jack-pine plains and frosty, acid swamps. The sheep-country of the near-arid West and rather inaccessible timbered slopes of the western mountains furnish another illustration.

Class Six.—Class Six is below the margin of profitable commercial utilization. There is no longer intrinsic value to the land. The land however may still yield indirect returns. Although commercial forests may not be grown, protective forests of great importance may belong here. The protection of water sheds and fixing of dunes are two familiar illustrations. It is perhaps inappropriate to place any surface that is growing things, even though they are not marketed, into the same class as barrens. Class Six possibly can be that group of land that is not barren, yet has no direct productive value, present or future. Most land of this sort has a significance, some a high significance, in the control of drainage and for the preservation of our game.

Class Seven.—Class Seven is the permanently non-productive residue, the barrens of rock, sand, submergence, cold, aridity. Except for rare building site value, the land has no money value, unless it be for scenery. It may be an agreeable foil to the productive surfaces. The empty spaces may possess recreational values. From the standpoint of a quality classification we are concerned here simply with the fact that these areas are the permanent blanks in our studies of production.

Summary of System.—The sketch of a possible classification has been made in the present tense, in terms of return but it is concerned especially with the possibilities of the future. It is an attempt to formulate a classification in terms of minimum essentials. There are only two exclusively agricultural classes of land set apart (1, 2). Then follows the marginal agricultural land and the equivalent high grade forest and grass land (3). Next is the agricultural submargin and its parallel normal grass and forest land (4). It would seem impossible to cut down to less than these four classes. There must also be a class for low grade forest and grazing land of commercial possibilities (5). Classes Six and Seven might possibly be consolidated but there is an advantage to separating out the barren land from the land that is unproductive but not barren. Expectation of return may be based on an evaluation of the environment. Where little or no development has taken place the environment furnishes the only means for judging land.[7] It is these wild and wasted lands of our country that suggest the type of land classification here proposed.

Adaptation to Field Use.—This is not a working classification. It is a discussion of a problem. A complete scheme is offered to see whether the idea of classification, in order to determine equivalence of quality of land, actually fits conditions. Possibly a field classification can be derived from such a general plan. If so, it must be by experimental classification of land in limited areas, and preferably in areas that are undeveloped. It is possible that a scoring system may be devised for judging land. Why should it be more difficult to measure the possibilities of land than to determine the mental equipment of students? Educational measurements have not made unnecessary existing systems, but they have supplemented our information. If the crops and stock that land produces can be scored by individual standards of perfection, is it too much to hope that the land may be judged by something more definite than an unanalyzed impression of an untrained assessor? In truth, our largest land loan institutions,

[7] The other readily available means of approach, sale price, does not serve in this connection. Where there are large areas of wild land the price is very commonly no index of quality.

the insurance companies in particular, are trying out improved means of land valuation. A scoring system on the plan of this classification would rate land with ideal environmental conditions at 100. Possibly trial would show the feasibility of assigning a certain maximum number to each item of the environment, with penalties for particular handicaps. Scoring systems are not built a priori, but by the agreement of competent judges.

Urgent Nature of the Problem.—A land classification presupposes soil studies and a systematic utilization study of the area. It is most appropriately part of a geographic survey or an economic land survey. It is needed now in particular to help settle the problem of our idle lands. This idleness entails a continued economic loss which the country cannot tolerate indefinitely. Before these areas can be developed successfully it is desirable to know the purposes for which they are best suited. Trial by pioneer settlement is painfully slow and wasteful of human energies, and the correction of mistaken judgments is very costly. Pioneering was a less expensive matter in our national economy so long as there was an abundance of good land that could be brought under cultivation without unusual difficulties. The faith in pioneering still persists, but the readily available lands are largely gone. The bulk of the remaining land is low grade and the really good tracts are not receiving the attention that they should have. The present-day pioneer is drawn largely from groups that do not possess the land sense that characterized in general our earlier settlement. Failures are at an alarmingly high rate.

The idle lands essentially are not going back into forests because of the notion that farming development may appropriate them. Yet probably the majority of them are not suited to such use, at least in the near future. Meanwhile we are facing a forest famine of appalling proportions. A reforestation policy cannot be put into effect until the forester has sufficient tracts of land assigned to his use. Our depreciated western grazing lands are causing stock men to look increasingly towards the cut over lands of humid parts of the country, yet they have no reliable information to tell them where they can undertake grazing with good hope of success. All the while there is a large amount of energy misdirected into the temporary clearing up of low grade land, largely because there is no information to guide the stump settler. A land classification of cut over lands alone might supply the key for the reconstruction of an area larger than the corn belt.

Beyond this task is the possibility that land classification may help to bring order into our tax system. Taxation possibly should be based directly on sale price. In many sections sales are not sufficient to

enable such a basis. It may further find a place in the application of rural credits. It is of course invaluable as an essential part of the future discipline of regional economic studies. It is a worthy problem to which the attention of scientist and producer alike may well be directed.

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THE INCREASING IMPORTANCE OF THE PHYSICAL CONDITIONS IN DETERMINING THE UTILIZATION OF LAND FOR AGRICULTURAL AND FOREST PRODUCTION IN THE UNITED STATES

O. E. BAKER

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THE PHYSICAL FACTORS.—The physical factors or conditions determine in large degree the utilization of the land in a region; and these physical factors become more important as the population increases, the knowledge and practice of agriculture advances, transportation facilities are improved, and the supply of capital and labor is increased and better distributed,—in brief, as agriculture and forestry become more highly organized and commercialized. These physical factors can be classified into four groups:

1. Topography, or land form; i. e., the configuration of the earth's surface, degree and direction of slope, roughness or smoothness of the land.

2. Soils, including both physical structure and chemical and bacteriological characteristics.

3. Moisture conditions; i. e., rainfall, snowfall, hail, fog, humidity, rate of evaporation.

4. Temperature conditions, particularly growing season temperatures and dates of occurrence of spring and fall frosts.

In addition, there are two factors, physical in nature but of a different character from those mentioned above, namely location and size of area.

The moisture and temperature conditions relate primarily to the atmosphere, the topographic and soil conditions primarily to the surface of the lithosphere, or what is commonly called the land.[1] Moisture and temperature conditions jointly constitute the climatic factors; likewise topographic and soil conditions may be said to constitute the edaphic factors. The climatic factors, in the extent and permanence of their characteristics, may be compared to genera in botanical classifications; while the edaphic factors of slope and soil, owing to the local variability and lesser permanence of their characteristics, may be compared to species. The climatic factors influence in particular the development of the general system of farming,—dairying, cattle ranching, cotton growing, etc.; whereas the edaphic factors more often determine the best utilization for a particular piece of land,—whether it should be used for crops, pasture, or forest, and if suitable for crops, whether for wheat, potatoes, corn, etc.

The extent and importance of the climatic restrictions upon the use of land for crops are not commonly appreciated. A third of the area of the United States and of Asia, almost one-half of Africa, and fully two-thirds of Australia are unsuited to crop production because of deficient moisture; a half or more of Canada and of Siberia, because of deficient temperature. The climatic factors also affect the use of the land indirectly because of their influence upon the comfort and health of the people. The tropics, where half of the arable land of the world is located, are probably not suited to permanent occupation by the white race. The yellow race, however, appears to possess a wider climatic range of adaptation and is able to live, labor and reproduce in the tropics.

The restrictions upon the utilization of land due to topographic and soil conditions are less extensive and more localized. In the United States not over one-fifth of the land is too hilly or too rough for crop production, and a still smaller proportion is unfitted for farming because of deficient fertility from other causes than lack of water. But although fully two-thirds of the humid eastern portion of the United States is arable or reclaimable land, it is unlikely that all of this land will ever be utilized for crops; much will remain in permanent pasture and probably more in forest. Even in densely populated Germany and France only about half of the land area is classified as arable.

The Normal Order of Land Utilization.—In the humid, temperate portions of the United States the best land, that most fertile and easily cultivated, is commonly used for crops; the next best land, either

[1] But it must be remembered that this is a narrow use of the word "land," and that in law and often in economics the word "land" includes both the air above the surface of the earth and the minerals which may lie beneath.

because of hilly topography, deficient fertility, or excessive moisture, is used for grazing; and the poorest land, usually mountainous, stony, or sandy, is left in forest. Along the rivers, however, particularly in the southern states, potentially the very best land may remain in forest because it is subject to overflow, or is poorly drained; and in the northern states there are numerous small areas of muck (not peat) land, still in native grass or forest, which would be excellent crop land after drainage. In the semi-arid and arid portions of the western states the use of the land becomes largely a matter of water supply rather than of soil. These arid and semi-arid lands are mostly used for grazing cattle, sheep, and horses; but in the valleys and on the valley slopes, where water can be profitably diverted from the streams or pumped from wells, irrigation is practiced. Only a comparatively small area in southeastern California and southwestern Arizona is so arid as to have no agricultural use at all.

Even in the better grades of land, such as are suitable for crops, wide differences in usefulness and value are commonly recognized. These differences depend not only on variations in the moisture, temperature, topographic, and soil conditions, but also on the crops grown. For potatoes, for instance, particularly their commercial production, a sandy loam soil is preferred, and for sweet potatoes an even more sandy soil; whereas corn does best on silt loam rich in humus, wheat on silt loam lower in humus, and hay on rather heavy soils, such as clay loams. In general, however, the best land, such as level or gently rolling silt loam derived from limestone or loess, is good for all the staple farm crops. The acreage in potatoes, the various vegetables, and other commercial crops of more or less peculiar soil adaptation, outside the localities which specialize in them, is small compared with the acreage of corn, wheat, oats, hay, and other staple crops.

The Order of Land Utilization and Rent.—These differences in the inherent productivity of land give rise to the payment of rent. As Ricardo expresses it in his famous exposition of the subject,—

"If all land had the same properties, if it were unlimited in quantity and uniform in quality, no charge could be made for its use, unless where it possessed peculiar advantages of situation. It is only, then, because land is not unlimited in quantity and uniform in quality, and because in the progress of population, land of an inferior quality, or less advantageously situated, is called into cultivation, that rent is ever paid for the use of it. When in the progress of society, land of the second degree of fertility is taken into cultivation, rent immediately commences on that of the first quality, and the amount of that rent will depend on the difference in the quality of these two portions of land.

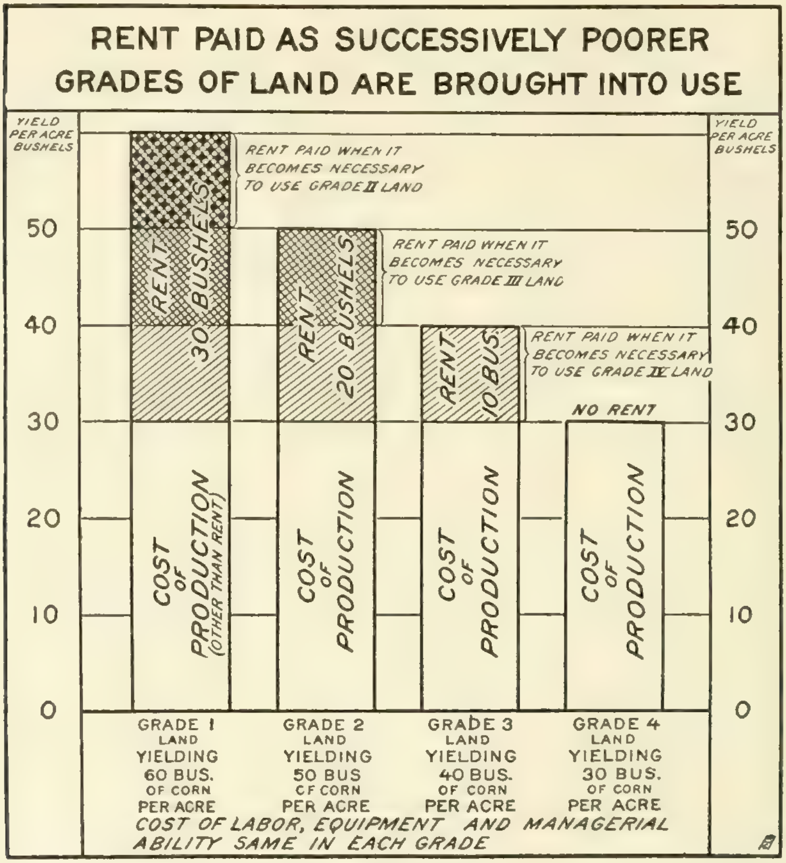

Fig. 1.—Illustrating the Ricardian Theory of Rent. When grade II land was brought into use rent began on grade I, and if the 10 bushels paid as rent was worth \$6.00, the land became worth, let us say, \$100. When grade III land was used, although production increased only 36 per cent (assuming equal areas for the grades of land), the rent of grade I land doubled and its value became \$200, while grade II land became worth \$100, and the total amount of rent paid on all land, hence the value of all land, trebled. When grade IV land must be used, although production increases only 20 per cent, the value of grade I land rises to \$300, of grade II land to \$200, and of grade III land to \$100; hence the total value of all land is doubled. In other words, as population increases and progressively poorer lands are brought into use, the value of land due to inherent superior quality increases much more rapidly than agricultural production,—from the standpoint of land values the geographic factors become increasingly important.

"When land of the third quality is taken into cultivation, rent immediately commences on the second, and it is regulated as before, by the difference in their productive powers. At the same time, the rent of the first quality will rise, for that must always be above the rent of the second, by the difference between the produce which they yield with a given quantity of capital and labor. With every step

in the progress of population, which shall oblige a country to have recourse to land of a worse quality, to enable it to raise its supply of food, rent, on all the more fertile land, will rise."[2]

The diagram (Fig. 1) illustrates the Ricardian theory of rent, and although the figures used are hypothetical they represent quite closely the situation in the Corn Belt as compared with adjacent areas of poorer land.

This explanation of land rent, made over a century ago, has found ample illustration in the agricultural development of the United States. At first settlement proceeded from the less fertile lands of the Atlantic states onto the more fertile lands of the Mississippi Valley, and as a consequence land values fell in the East. But as settlement then advanced into the sub-humid areas of the western states, land values rose again. In the more fertile portions of the United States this rise in value of farm land has been very rapid, in the Corn Belt the value per acre more than doubling between 1900 and 1910, and doubling again between 1910 and 1920. The values of poorer lands, on the other hand, have increased much more slowly, in New York, for instance, increasing 28 per cent from 1900 to 1910 and 12 per cent from 1910 to 1920.

This rapid rise in land values, and this increasing spread of the difference in value between excellent and poor or fair land, is owing primarily to the fact that population has increased more rapidly than the land supply. Land values have been more or less a compromise between present price of farm products and anticipated higher prices occasioned by increasing population, as shown in Figure 2. Since about 1896, when the price of food began to trend upward with increasing population, the rise in land values has been rapid. The decade 1890-1900 is a very significant period in American history, in that it marks the turning point in the relation of land supply to population. Since then not only has the acreage of improved land per capita of the population decreased, but also the new land brought into agricultural use is, in general, of a progressively poorer quality. It is notable how much more rapidly the excellent land of Iowa has risen in value than the poor-to-good land of New York. The low price of land in Iowa during the earlier decades, however, was largely owing to later settlement and lack of adequate transportation facilities. But the more rapid rise during the last three decades, as compared with New York, has been due principally to the greater surplus productivity of Iowa land available for payment of rent.

The Trend of Land Utilization.—The good land of the United States has been practically all brought now into agricultural use; that which

[2] Ricardo, David. Principles of Political Economy. Gonner Edition, pp. 46-47.

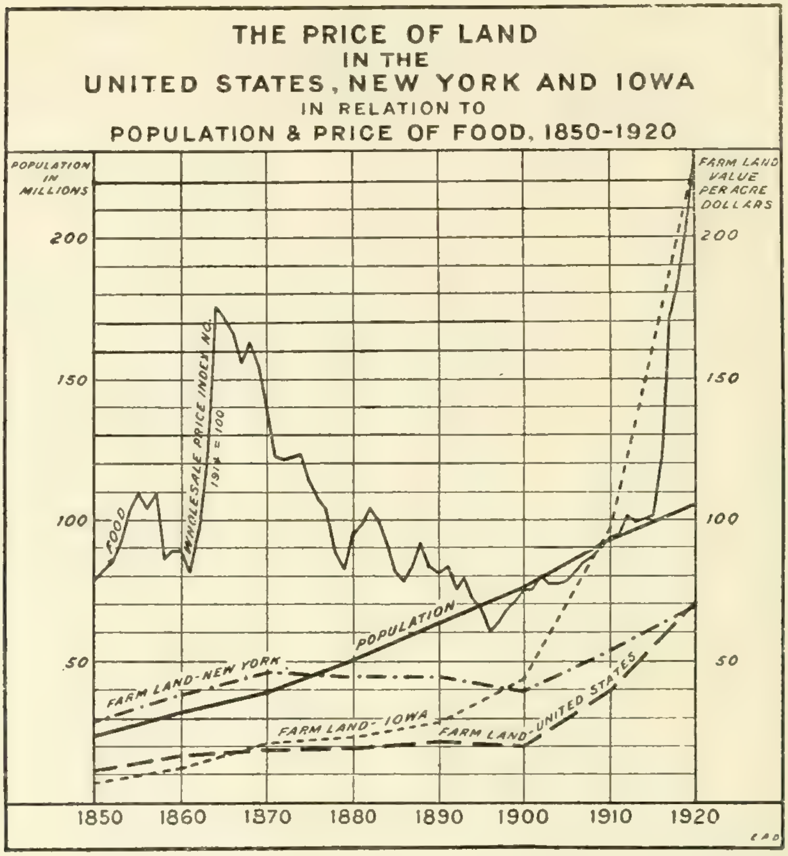

FIG. 2.—Statistics of the price of land and of population are from the Federal Census, of prices of food from the *Annalist*, New York, July 4, 1921, "The Long Time Trend of Prices in the United States," by Ralph S. Harlin, of the Russell Sage Foundation. It will be noted that the price of farm land for the United States as a whole remained practically stationary from 1870 to 1900, constituting a compromise between the declining prices of food products and the increasing population; but that since 1900 the price of land has risen more rapidly than population, and in the case of Iowa about as rapidly as the price of food. The more rapid increase in value of the excellent land of Iowa as compared with the poor to good land of New York is noteworthy.

remains unimproved is, with few exceptions, too wet or dry, too steep or stony or infertile for the profitable production of crops.[3] Indeed, the returns from the 1920 Census of agriculture indicate that the expansion of the farm area, particularly in the more hilly or less fertile

[3] The amount of such land which it is possible by various means of amelioration to bring into use for crops is probably over 300 million acres, or three-fifths of the present acreage of improved land. It includes about 75 million acres of drainable land and probably 30 million acres of irrigable land, which can be reclaimed when the price of farm products justifies the cost of reclamation. Also, there is perhaps

parts of the United States, has already proceeded farther than present conditions justify. The increase of land in farms between 1910 and 1920 was practically confined to the western half of the country, every state in the humid and longer settled eastern half showing a decrease, except Michigan, Wisconsin, and Minnesota, whose northern portions have been undergoing settlement, Missouri, whose Ozark Plateau is still in process of agricultural development, Arkansas and Florida, in which states large areas of land have been reclaimed by drainage.

Yet, despite the decrease of 12 million acres of farm land in the eastern half of the country, the area in crops increased 25 million acres. The trend during the decade was toward the more intensive use of the more fertile or favorably situated land, that is, its use for crops rather than pasture; and, apparently, toward the less intensive use of the less fertile land, that is, its use for unimproved pasture and forest. Increased production has been achieved by closer adaptation of the use of the land to the geographic conditions, and by greater concentration of labor and capital on the more productive lands.

The history of agriculture in the United States shows that with each advance in transportation facilities, in agricultural technique, and in economic organization, the correlation between the four physical factors (topography, soil, moisture, and temperature) and the use of the land has become closer. The control of geographic conditions over agricultural development, instead of being mitigated by the progress of science and invention, has been intensified and enforced. The commercialization of agriculture and the keen competition resulting between different regions makes the production of a crop sensitive even to the more minute advantages or disadvantages in geographic conditions which a district may possess, and compels shifts in crop production or in use of land to be made with an alacrity unknown in previous ages.

THE INCREASING IMPORTANCE OF TOPOGRAPHY.—The invention and extensive use in the United States of farm machinery, which is constantly becoming more efficient and essential to profitable crop production, has greatly increased the influence of topography in determining the utilization of land. Hilly regions, in addition to the former drawbacks, even under a hand-labor system of farming, of lesser accessibility as compared with level lands and consequently greater costs of marketing, also usually of shallower and less fertile soils, now suffer from the further disadvantage of being poorly adapted to the use of modern farm machinery. Certainly in the production of cereal crops,

175 million acres of forest and cut-over land not requiring drainage, but in many cases deficient in fertility, which will be suitable for crops after clearing; and a considerable area of stony or infertile pasture land in the East and potential dry-farming land in the West whose use for crops is not justifiable at present prices of agricultural products and labor.

and probably also of hay, one man can farm twice the area of level land that he can of hill land; and if the level land be more fertile, as is usually the case, the handicap of the hill-land farmer is further increased.

Illustration from New England.—Much rolling-to-hilly upland in New England, for instance, formerly used for crops and pasture is now in forest; while the level and more fertile bottom land of the Connecticut Valley, previously cropped with corn, grain and hay, is now devoted largely to tobacco, onions, and other vegetables, and is cultivated with an intensity unknown before.

The first step in enforcing the less intensive utilization of the hill lands and the more intensive utilization of the valley lands in New England was taken when the domestic, self-sufficing agriculture of the colonial and early national eras gave way to our modern commercial system of production. The transfer of industry from the home to the factory involved the transport of agricultural products from farm to city, and of manufactured products from city to farm, and in this transportation of commodities to and fro the more accessible, level, valley lands possessed a great advantage over the isolated farms in the hills.

The second stage in the gradual abandonment of the hill lands for crop production, especially of the steeper slopes, was ushered in by the introduction of elaborate farm machinery on the valley farms, but more particularly on the level lands of the rapidly developing western states. Prior to the Civil War many farmers in the hills of New England grew wheat for home consumption in little patches of two or three acres, seeded by hand, harvested with the sickle or cradle, threshed with the flail, and ground on shares at the local mill. But the competition of western grain, first from the Genesee Valley of New York and later from Ohio and Illinois, where farming machinery was extensively used, caused the gradual abandonment of these miniature wheat fields; so that since the Civil War New England farmers, as well as city folk, have been almost wholly dependent upon the West for their bread. Undoubtedly also the greater fertility of the lands in the West made competition by the hill farmers in small grain production practically impossible.

This western competition became possible only after the construction of the Erie Canal and the building of the railroads. These improvements in means of transportation, although preceding somewhat in time the invention of modern farm machinery, do not seem to have rendered western competition fully effective until some years after the Civil War. It was then that the Prairies and eastern portions of the Plains were most rapidly brought into use for crops, and the consequent contraction of the "improved" area in New England definitely

set in. From 1875 to 1885, and again from 1892 to 1898, the prices of farm products were particularly low and agriculture was declining in New England.

The latest stage in this economic evolution, dating from about the year 1900, is characterized by the more intensive use of the valley lands for the production of vegetables, city milk, and other bulky and perishable products which the rapidly increasing urban manufacturing population has required. These products cannot be grown so well on the hill lands because of the greater cost of transportation, and also because of the rougher topography and less fertile soil, while western competition is prohibited both by the great cost of transportation and by the perishable character of the products. The use of artificial fertilizer, and of animal manure from the cities, has greatly facilitated the development of this fourth stage in the agricultural history of the region. Unquestionably also the influx of Poles and other immigrants, accustomed to hand-labor and a low standard of living, has been an important factor in promoting the recent period of prosperity. Land in the Connecticut Valley suitable for onions has recently sold as high as $400 an acre, and rentals of $25 to $50 an acre are frequently paid.

IMPROVED AND UNIMPROVED LAND IN NEW ENGLAND, 1850 TO 1920

ACREAGE IN CROPS WITH ACREAGE RETURNS 1879-1919, AND VALUE OF ALL CROPS, 1899–1919

Year	Total Farm Land (Thousands of Acres)	Improved Land (Thousands of Acres)	Unimproved Land (Thousands of Acres)	Land in Crops (1) (Thousands of Acres)	Value of All Crops (Millions of Dollars)
1850	18,367	11,151	7,216	No figures	No figures
1860	20,111	12,216	7,895	" "	" "
1870	19,570	11,998	7,572	" "	" "
1880	21,484	13,148	8,336	5,215(2)	" "
1890	19,756	10,739	9,017	4,924	" "
1900	20,549	8,134	12,415	4,666	95
1910	19,715	7,255	12,460	4,422	141
1920	16,991	6,115	10,876	4,051	275

(1). Omitting fruits, vegetables, forage, and nursery products, statistics of which were not gathered until 1890 and 1900

(2). To which should be added an unknown acreage of permanent hay meadows.

The control of topographic conditions over agricultural development in New England, instead of being mitigated by the progress of science and the economic organization of agriculture and industry, has been intensified and enforced. It is significant also that the commercialization of agriculture and the introduction of farm machinery have raised the margin or general level of the utilization of land for crops, liberating the poorer hill lands for use for pasture or, more commonly, for forest. Agricultural production has not decreased materially in quantity, if at all, and has increased in value. The acreage of hay and

forage, for instance, which occupies 80 per cent of the crop land of New England, has decreased gradually since 1880 (the first census year for which figures of acreage are available), but the yield per acre has increased more rapidly than the acreage has decreased. Consequently, the production of hay and forage has shown an increase each census year except one, and in 1919 was 30 per cent greater than in 1879, as shown in the following table:

HAY AND FORAGE IN NEW ENGLAND

(Acreage, Production, and Value in Thousands; Federal Census)

	1879	1889	1899	1909	1919
Acreage..............	4,254	4,180	4,050	3,797	3,574
Production (Tons)	4,080	4,565	4,577	4,660	5,309
Yield per Acre "	.96	1.09	1.13	1.23	1.49*
Value................	....	....	$43,662	$59,113	$108,946

* This increase in yield per acre is owing largely to increased use of forage crops, particularly corn silage and forage. In 1879 forage crops, apparently, were not included in the census figures; in 1899 they totaled only 103,268 acres, but in 1919 the area in the various forage crops amounted to 202,346 acres. The yields per acre of hay only were as follows: 1879=.96 ton; 1889=1.09; 1899=1.00; 1909=1.01; 1919=1.14 ton.

The Federal agricultural figures are available only by counties, and as all counties in New England include both hill and valley land (except Barnstable county, Mass., which is sandy), the Federal Census figures are not suitable for comparison of the trend in land utilization in the hill with that in the valley districts. Happily, however, the state of Massachusetts took a very complete census of its resources and production each decade from 1865 to 1905, tabulating the returns by towns (corresponding to townships in the West), and it is from these state census reports that the following figures are derived.

CHANGES IN THE USE OF LAND IN HILL[1] AND VALLEY[2] TOWNSHIPS, HAMPSHIRE COUNTY, MASSACHUSETTS

State Census Year	"Cultivated" Land (Crop Land) Acreage		"Unimproved" Land (Mostly Permanent Pasture)		Woodland in Farms Acreage	
	2 Valley Towns	4 Hill Towns	2 Valley Towns	4 Hill Towns	2 Valley Towns	4 Hill Towns
1865	9,031	10,689	6,393	28,000	2,969	10,357
1875	11,716	12,121	5,047	29,569	2,822	12,683
1885	11,941	12,000	5,514	28,628	4,496	18,403
1895	11,701	10,087	5,291	21,657	4,349	28,708
1905	12,156	10,787	4,084	22,506	6,491	35,884

[1] Chesterfield, Cummington, Huntington and Pelham

[2] Hadley and Hatfield.

The acreage of "cultivated land" in the valley townships, it will be noted, was higher in 1905 than in any prior census year, indicating that slight extension of crop area has accompanied intensification of culture; while the acreage of "cultivated land" in the hill townships reached its high point in 1875, then declined to 1895 and afterward increased slightly to 1905, when it was practically the same as in 1865. For the state as a whole the amount of "cultivated land" increased from 1865 to 1905. On the other hand, the acreage of "improved" land, according to the Federal Census, both for Hampshire County and for Massachusetts as a whole, has declined constantly since 1880, and is now only about half what it was forty years ago. This apparent discrepancy between state and federal statistics is doubtless to be explained by differences in definition. "Cultivated land," according to the state census, includes land in crops only; whereas "improved land" of the Federal Census, at least in 1880, when a separation was made, included over twice as much "permanent meadows and pastures" as "tilled land and rotation grasses." Evidently, the decrease in "improved" land shown by the Federal Census has been due almost wholly to diminution of amount of improved pasture rather than to lessening area in crops. Much of this improved pasture has gradually reverted to unimproved pasture, and much of this unimproved pasture has, in turn, reverted to woodland. That this reversion to woodland has occurred more rapidly than the transformation of improved into unimproved pasture is indicated by the decrease in state census figures of "unimproved land." Woodland in farms more than doubled in extent during the forty years, 1865 to 1905, in the valley towns of Hampshire county, more than trebled in the hill towns, and nearly doubled in the state as a whole. A recent writer remarks concerning Massachusetts, "In the thirty years, 1880-1910, the forest was able to retake from the field half of the territory the hardy farmer had won, and has left the state only a little more than a million acres of improved land where formerly it had considerably more than two million."[4] This is true, apparently, if the words "retake from the field" are understood to refer to pasture.

The average value of farm land and buildings per acre in the four hill townships declined from $22 in 1865 to $18 in 1905, reaching a low point of $14 in 1895; and the average value in the two Connecticut Valley townships increased during the same period from $101 to $154, likewise marking a minimum of $85 in 1895.

In this connection it may be observed that fairly good soil is apparently worth much more than poor for forest and pasture as well as for crops, the ratio of value of valley to hill land remaining more or

[4] Showalter, William Joseph, "Massachusetts—Beehive of Industry." *Nat. Geog. Mag.*, March, 1920.

less constant for the forty years at about five to one for "cultivated land;" three or four to one for "unimproved land" (mostly pasture), and about two to one for "woodland." It is also significant that the value of agricultural products per person engaged in agriculture has throughout the forty years ranged from one-half to two-thirds as much in the hill towns as in the valley. This fact largely explains why the value of valley lands per acre should be so much higher than that of the hill lands, beginning at a ratio of about four and one-half to one in 1865, but rising to eight and one-half to one by 1905. The number of persons engaged in agriculture remained practically constant in both hill and valley towns during the 40 years. It should be noted that the figures of average annual value of agricultural products per person include a duplication of the value of the hay and oats fed to live stock, and also that expenditures for feed purchased, for rent or interest, etc., should be subtracted in order to arrive at the farmer's real income.

A farm management survey of a New Hampshire district, similar in character to the hill towns of Hampshire County, showed an average labor income of $256 in 1909. This is not a living wage, according to modern American standards, and these hill farms probably never have paid an income equal to that obtainable in either the valley farms or factories to-day. The reversion of these hill lands to forest is a blessing, not a misfortune; timber and forest products are as essential to the prosperity of the people as hay or grain. In Massachusetts some of the pine forests which have sprung up in old pastures since the Civil War are reported to be yielding to-day an average net annual income of $5 per acre.[5] The progress of invention and the regional competition of modern commercial agriculture are merely enforcing the control of geographic conditions and compelling these lands to be used more economically from the standpoint of human labor. It is probable that the fuller use of these hill lands for forest, by affording winter employment, will permit the cultivation of more farm land in summer than would otherwise be possible. Agriculture in New England has advanced not receded; the land is being utilized more efficiently and in general more profitably than ever before.

Illustrations from Other Hilly Sections.—The same trend toward less intensive utilization of hilly land, that is, for forest and pasture rather than crops, which is so characteristic of New England agriculture, can be seen in many other hilly or mountainous regions, though the trend is, in most cases, not so striking. The accompanying table provides figures from the last five census reports for four hill land counties as compared with four lowland and fairly level counties in New York, in Pennsylvania, in Virginia and West Virginia, in North Carolina,

[5] Letter from Mr. P. S. Lovejoy to the writer, 1921.

and in California. It will be noted that the approximate farm income in 1909 (the only year for which figures are available) was considerably higher in each group of lowland counties than in the corresponding group of hill land counties. In New York and Pennsylvania the acreage of improved land, also the "country population," in the hill land counties has declined notably since 1900. In the lowland counties improved land and population has also decreased, but at a much lesser rate. Value of land and buildings per acre since 1900 has increased about 65 per cent in the hill land counties, and in the lowland counties about 100 per cent.

In Virginia and West Virginia the acreage of improved land in both hill land and lowland counties, as well as "country" population, has remained almost constant since 1900, and the value of farm land in the two groups of counties has increased at about the same rate. The good showing of the hill counties in these states is probably owing to the considerable area of fertile limestone soils they include. In North Carolina the acreage of improved land in the hill counties has decreased markedly in the past decade, and although the value of land has advanced, the rate of increase is considerably less than in the lowland counties. Population in the hill land counties has decreased slightly and in the lowland counties has increased 5 per cent each decade. In California the decrease in improved land in the hill land (Sierra) counties has been notable, and has occurred to a less extent in the lowland (Great Valley) counties also, owing largely to the shift from grain growing to more intensive types of farming. "Country" population, accordingly, increased greatly in the lowland counties (50% in 20 years), whereas in the hill land counties it decreased nearly one-third.

The accompanying maps (Figures 3 and 4), showing decrease and increase in acreage of improved land between 1910 and 1920, reveal that the decrease occurred largely in districts of hilly topography, whereas the increase occurred principally in the Great Plains region, and on the Plateaus of Idaho and eastern Oregon and Washington. Here the broad, level bench-lands permit the use of large scale machinery, with a consequent cost of grain production per acre so low that it may be profitable to cultivate the land, with the summer fallow system, even though a crop is secured only in alternate years.

THE INCREASING IMPORTANCE OF ORIGINAL SOIL FERTILITY.—Inherently fertile land not only yields permanently a larger quantity of the staple farm crops than land less fertile, but also its capacity to utilize profitably the application of successive increments of capital and labor increases with its fertility. Because of this greater capacity to utilize capital and labor, as well as because of its greater produc-

The Trend in Acreage of Improved Land, Value of Farm Land Per Acre, and Number of "Country Population," Four Hill Land as Compared with Four Lowland Counties in Five States

State	Approximate Average Farm Income	Improved Land Total Acres (Thousands)					Value Per Acre of Farm Land and Buildings					Number of "Country" (Unincorporated) Population (in Thousands)		
	1909	1880	1890	1900	1910	1920	1880	1890	1900	1910	1920	1900	1910	1920
New York:														
4 Hill land counties*	$ 475.00	1770	1739	1730	1680	1447	$26.40	$28.90	$25.90	$33.10	$ 43.40	147	137	117
4 Lowland counties	797.00	1103	1073	1092	1096	1025	72.90	66.00	56.30	84.20	113.40	101	100	88
Pennsylvania:														
4 Hill land counties	173.00	135	154	160	144	138	22.80	23.70	22.30	27.40	38.50	56	52	47
4 Lowland counties	670 00	1156	1165	1176	1173	1143	82.00	74.80	69.70	91.40	122.40	180	173	172
Virginia and West Virginia:														
4 Hill land counties	474 00	268	313	377	342	360	7.30	8 00	8.90	14.30	28.70	35	34	33
4 Lowland counties	645.00	697	726	782	793	786	19.10	26.50	26.50	48.00	90.50	86	83	84
North Carolina:														
4 Hill land counties	279 00	251	299	361	400	336	5.10	8.60	10.00	21.00	39.40	59	63	61
4 Lowland counties	381.00	479	514	559	601	558	7.20	8.90	9.20	21.00	45.20	90	95	100
California:														
4 Hill land counties	471.00	205	213	164	157	139	9.00	13.80	9.60	14.80	23.40	31	27	22
4 Lowland counties	1125 00	1889	1856	1920	1784	1660	17.80	36.30	21.50	53.50	119.40	50	64	76

*The counties selected are as follows:

New York—Hill land—Cattaraugus, Delaware, Steuben, Sullivan.
Lowland—Livingston, Niagara, Orleans, Wayne.

Pennsylvania—Hill land—McKean, Cameron, Carbon, Pike.
Lowland—Adams, Green, Lancaster, Lehigh.

Virginia and West Virginia—Hill land—Alleghany, Highland, Va., and Hampshire, Pendleton, W. Va.
Lowland—Augusta, Botetourt, Frederick, Rockingham, Va.

North Carolina—Hill land—Ashe, Haywood, Macon, Mitchell.
Lowland—Davidson, Granville, Iredell, Union.

California—Hill land—Eldorado, Toulumne, Plumas, Nevada.
Lowland—Butte, Merced, San Joaquin, Yolo.

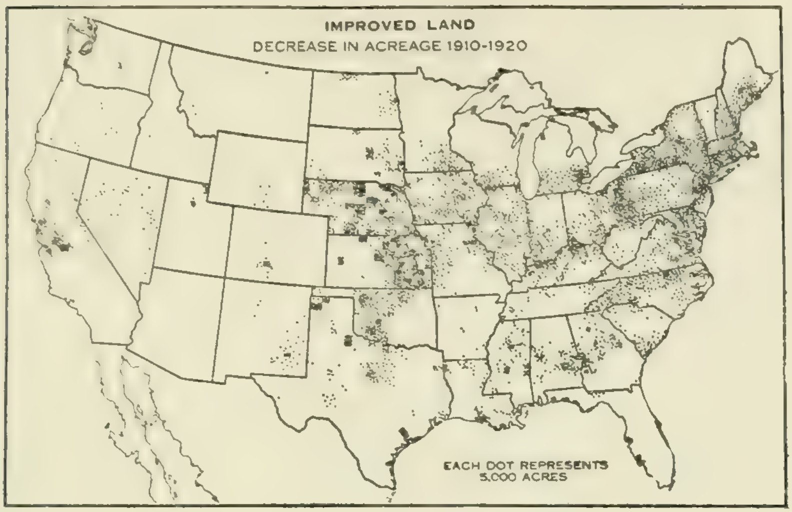

FIG. 3.—Decrease in acreage, 1910-1920

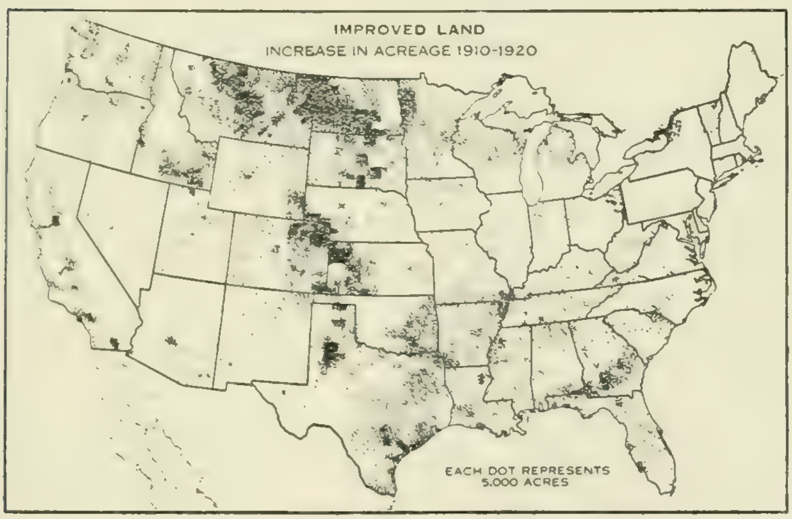

FIG. 4.—Increase in acreage, 1910-1920

tivity with the application of the same capital and labor, the best farm land has, in general, increased more rapidly in value than good farm land, good farm land more rapidly than fair land, and fair farm land more rapidly than poor land.

Illustrations from Ohio and Illinois.—In the following table the counties of Ohio and Illinois have been divided into four groups on the basis of decreasing value of farm land per acre in 1900, and it will be

noted that the increase in value of the best and good land during the following decades was not only much greater absolutely but also somewhat greater relatively than the increase in value of the poor land.

In thus grouping counties together on the basis of value of farm land per acre the effects of topographic conditions have been inevitably included with those of soil, but in these states the soil conditions are unquestionably of greater importance than the topographic, while climatic conditions in each state are sufficiently uniform as to have no material effect upon the value of land.

CHANGES IN VALUE OF FARM LAND PER ACRE

Counties of Ohio and Illinois Classified into Four Groups According to Value in 1900

Average Value Per Acre

Ohio	First group of 22 counties of highest land value in 1900	Second group of 22 counties	Third group of 22 counties	Fourth group of 22 counties of lowest land values
1900	$ 51.30	$ 37.30	$ 28.90	$18.10
1910	82.60	65.60	45.10	23.70
1920	135.30	109.50	67.90	36.00
Increase in value 1900–10, Amount	$ 31.30	$ 28.30	$ 16.20	$ 5.60
Per Cent	61%	76%	56%	31%
Increase in value 1910–20, Amount*	$ 52.70	$ 43.90	$ 22.80	$12.30
Per Cent	64%	67%	51%	52%

Average Value Per Acre

Illinois	First group of 25 counties having highest land value in 1900	Second group of 26 counties.	Third group of 25 counties.	Fourth group of 26 counties.
1900	$ 68.50	$ 50.50	$ 33.60	$19 00
1910	145.30	102.50	70.10	35.90
1920	259.60	180.80	114.40	50 60
Increase in value 1900–10 Amount	$ 76.80	$ 52.00	$ 36.50	$16 90
Per Cent	112%	103%	109%	89%
Increase in value 1910–20 Amount*	$114.30	$ 78.30	$ 44.30	$14.70
Per Cent	79%	76%	63%	41%

*The increase in value of the best land between 1910 and 1920 would be even more notable if the classification were based on value in 1910 instead of continuing to use the 1900 basis.

Illustration from the Upper Lakes Region.—The same forces which have caused good land in Ohio, Illinois, and in general throughout the United States to increase greatly in value and poor land to increase more slowly,—in fact, relative to the purchasing power of the dollar, actually to decrease materially in value in many localities,—has made unprofitable the clearing of much poor, or even fair, land in the northern portions of the Lake States. There are probably 10,000,000 acres of sandy or peat land in Michigan,[6] 5,000,000 acres in Wisconsin,[7] and about the same in Minnesota,[8] which under present economic conditions cannot be used profitably for crop production, but should, instead, be utilized for forests. Some of this land has already been cleared, often at heavy expense, farmed for a few years, and then abandoned. Not merely farms, but villages of several hundred people have been abandoned and have disappeared from the map. To quote from a recent government publication:

"I spent five days around Harrison and I saw abandoned farms in great numbers. I saw 100 farmhouses boarded up and desolate, and in some of them were the cook stoves, rocking chairs, and a lot of other stuff left behind, for they evidently had no money to cart it away. A whole lot of life's tragedy is written on the Michigan sand barrens. New settlers are going in right along to try the same old experiment of thrashing a living out of the sand and nothingness, and will meet with the same result."[9]

Undoubtedly much of this settlement on poor soils has been due to misrepresentation and fraud by land speculators and their agents. As an experienced farmer expressed it, "Of course you can farm these lands. All you need is two things—a shower of rain every week day and a shower of fertilizer on Sunday." But also undoubtedly a portion of the failures is to be attributed to the increasing productivity of the richer soils, both local and in other regions.

That the abandonment of these farms was not due to poor transportation facilities is evident from the fact that many of these unsuccessful farming areas are located directly on a railroad; and, that it was not due to climatic conditions, is shown by a survey made by the Federal Office of Farm Management in 1914 of 800 farms in northern Michigan, Wisconsin and Minnesota, most of which were located on

[6] Lovejoy, P. S. Farms vs. Forests. Twenty-first Annual Report, Michigan Academy of Science, 1919, p. 201.

[7] Estimated by the writer on basis of data furnished by W. J. Geib, of the Wisconsin Soil Survey.

[8] Estimated by the writer on basis of maps of Surface Formations of Minnesota, by Frank Leverett, contained in Bulletins 12, 13, and 14 of Minnesota Geological Survey (1915, 1917, 1919).

[9] Quoted by Dana, Samuel T. Forestry and Community Development: Bulletin No. 638, U. S. Dept. of Agriculture, 1918, p. 15.

the better soils of the region.[10] Fifty of these farms having between eighty and one hundred acres of tillable land, in addition to paying six per cent on the investment, gave an average labor income of $200, and those farmers having 180 acres tillable secured an average labor income of $500. The farmers having less than fifty acres, on the other hand, received no labor income, and did not even secure five per cent on their investment. Success or failure, therefore, on these better soils in the region depends on the amount of cleared land, which is in turn dependent largely on the amount of capital available. Dairying is the most profitable and is rapidly becoming the dominant type of farming, and dairy farmers having one hundred and twenty acres of tillable land obtained practically as large labor income as those averaging one hundred and eighty acres. Dairy farming in units of one hundred to one hundred twenty acres is a moderately intensive use of the land. Here, as elsewhere, the trend appears to be toward the more intensive utilization of the better land and the less intensive utilization of the poorer land.

It is fortunate that accompanying the increasing unprofitableness of utilizing the sandy lands for crops in this region is the prospect of an increasing profitableness of utilization for forest. The price of lumber is now such, and despite anything that can be done is likely to remain such for 50 years at least, as to warrant the protection of the young forests from fire in this region, and probably even the planting of some of the land to white or Norway pine, with the anticipation of a fair return upon the investment. If the pressure of population be so great fifty years hence as to exceed the limit of production of the better soils, it will then be fitting to consider the clearing and utilization of these sandy lands for crops; but meanwhile it should be recognized that every advance in agricultural technique and in transportation facilities, not only in the United States but even in Siberia or the tropics, tends to make the utilization of these poor soils for crops progressively more precarious, if not impossible.

Illustrations from California.—In semi-arid and arid, as well as in humid regions, the importance of original soil fertility is being increasingly recognized. Nearly all arid soils were formerly esteemed fertile, provided sufficient moisture was available, but the partial failure of some irrigated projects in the West, owing to sandy or otherwise infertile soils, has called attention to the fact that arid as well as humid soils vary greatly in their productivity. Moreover, the margin of utilization of land for crops appears to be rising in parts of the West just as it has risen in certain parts of the East. In California the trend

[10] McDowell, J. C., and Walker, W. B. Farming on the Cut-over lands of Michigan, Wisconsin and Minnesota: Bull. No. 425, U. S. Dept. of Agriculture, 1916, p. 9.

toward the more intensive use of the more fertile land and the less extensive use of the less fertile land has been exceptionally rapid.

Between 1899 and 1909 the acreage of wheat in that state declined from 2,683,000 to 478,000 acres, or over 2,200,000 acres. This decrease was distributed throughout every wheat producing county in the state except one, but was most marked in the San Joaquin and Sacramento valleys. Wheat had been extensively grown in these valleys for thirty years or more, in some localities almost continuously, yet there was no appreciable diminution in the average yield per acre for the state as a whole, according to the estimates of the Federal Bureau of Crop Estimates; nor did the price decline, but in the decade 1900-1909 increased nearly twenty per cent over that in the previous decade and equalled that in the decade 1880-89 when the acreage was increasing rapidly. In the absence of detailed statistics of wheat acreage to compare with soil types it seems reasonable to give credence to the popular and almost universal impression among farmers in that state that thirty years, more or less, of continuous cropping to wheat " wore out " the fertility of the poorer soils. As one Californian of wide experience remarked to the writer, " It was wheat, then barley, then rye, then good-bye." The persistence of wheat production on the better soils would account for the maintenance of the yield per acre.

This popular impression is supported by the use made, presumably, of the former wheat land. Only one-third of this land, apparently, has been used for crops, and two-thirds has reverted to pasture or remained unused. Rather one should say that there occurred between 1899 and 1909 a decrease in wheat acreage of 2,200,000 acres, and of rye and orchard fruits about 120,000 acres more; while during the same period hay and forage increased 294,000 acres, barley 166,000 acres, beans and peas 113,000 acres, grapes 28,000 acres, vegetables and potatoes 76,000 acres, various other crops 133,000 acres; thus showing a net decrease of crop land of 1,500,000 acres. The decrease in improved land was only 569,000 acres; so presumably over 900,000 acres of this former crop land reverted to improved pasture, of which there were nearly 3 million acres in 1910; and most of the remainder, or its equivalent of improved pasture, apparently reverted to unimproved pasture, of which there were over five and a half million acres in 1910. Unfortunately pasture figures are available only for 1910; so it is impossible to determine precisely how much of this former crop land became improved pasture, how much unimproved pasture, and how much went out of use altogether.

Illustrations from Kentucky.—The increasing importance of the peculiar suitability of certain soils for a particular crop is well illustrated by the production of white burley tobacco in the Blue Grass basin and

adjoining counties in Kentucky. In a study of the cost of production in 1919 it was found that the average yield per acre of tobacco on the good land in the central portion of the basin was three-fourths greater than on the less fertile land in Scott county. Moreover, the quality of the tobacco grown in the central district was better, the price received by fifty-three farmers averaging sixty cents per pound, while that from the twenty-eight farms studied in Scott county brought only an average of thirty-eight cents. The cost of production per acre other than rent was only ten per cent greater in the central district than in Scott county; indeed, the hours of horse labor per acre required in the central district was twenty per cent less and of man labor only three per cent more than in Scott county, but the wages paid were somewhat higher. The average value of tobacco land in 15 of the central district farms was $320 per acre, in 10 Scott county farms $85. The average share rent (one-half) in 1919 amounted to more than the value of the land,—$406 on 33 farms in the central district and $135 on 14 farms in Scott county. The average cash rent was $102 in the central district and $52 in Scott county. This seems very high rent, but the price of tobacco was extraordinarily high, and, moreover, only good land can be profitably utilized for burley tobacco, land inherently fertile and free from root rot. Land not suitable for tobacco seldom rents for more than $20 an acre.

The introduction of tobacco, therefore, into the Blue Grass basin, a crop requiring much more intensive use of the land than the corn, wheat, and pasture system of farming previously followed, has not diminished but instead has greatly increased the previously existing differences in both the gross and net productivity of the land. The rent of poor land in 1919 was little greater than before the introduction of tobacco; the rent of the best land had increased ten fold. Here, as elsewhere, increasing intensity of cultivation has raised the value of inherently fertile land more rapidly than that of less fertile land, both absolutely and proportionately.

The Increasing Importance of the Moisture Factors.—The development of modern agricultural machinery,—which has greatly increased the acreage of crops that a man can handle, especially of the small grains,—the increasing knowledge of dry-farming practices, and the breeding of drought resistant varieties of plants, particularly wheat, has extended notably the area available for crop production in the United States. But in the semi-arid areas of the West the small grains are soon found to be precarious crops, and the necessity of diversification and the adoption of systems of farming better adapted to the fluctuating seasonal conditions become apparent. Consequently, the adaptation of the varying soils and sites to different uses, especially with reference

to moisture conditions and requirements, is being studied in more and more detail. Provision is now more frequently made to irrigate part of the valley bottoms by means of flood water, or otherwise, in order to obtain hay or forage for winter feed; and it is becoming recognized that only dark brown, level land on the higher benches, where the rainfall is a little heavier, should be plowed up and put into "dry land" crops, all other non-irrigable land remaining in native pasture. In other words, as competition for the use of the land becomes keener and arid agriculture, like humid, becomes more commercialized, as the better lands rise in value and their productivity must be increased, it becomes necessary to fit the use of the land to the moisture conditions with more and more care and precision.

Formerly most of the semi-arid portion of the United States consisted of unfenced grassy plains, often intermixed with brush and flowering plants, grazed by roaming herds of cattle or bands of sheep. But now conditions are rapidly changing. Homesteaders have settled on most of the land that affords any promise of ever being fit for crop production; in some places succeeding in developing a farm, or selling to farmers who can succeed, usually by more intensive culture; in other and usually drier places selling out to stockmen who allow the fields that have been plowed up to revert to the native pasture grasses. Hence, in the semi-arid region, as elsewhere in the United States, the trend is toward the more intensive utilization of the better, in this case the moister land, and the less intensive utilization of the poorer land.

Illustrations from Montana.—This trend is particularly noticeable in Eastern and Central Montana. The wave of homesteaders that swept onto the semi-arid plains of this state during the wet years 1915 and 1916 may be separated into two sections: that which moved into the drier parts of Richland, Dawson, Blaine, Hill, and Toole counties in particular is slowly disappearing, and many of the young men and women are moving onto the irrigated lands and into the villages and cities scattered along the river valleys, or else are returning east. The abandoned land is being bought up mostly by cattlemen, some is reverting to the government, other tracts to the state for taxes, while the old fields are growing wild sunflowers or Russian thistles, and will eventually be reclaimed by the native pasture grasses. The other stream of migration which moved into the counties in the northeastern corner of the state is, in part, succeeding and is transforming the "open range" into fenced farms with cultivated fields and improved pastures. The difference between success and failure is measured by only two or three inches of average annual precipitation.

Illustrations from New England and the Gulf Coast.—The use of land for the production of certain crops may be limited by

excessive as well as by deficient moisture. Thus, in New England, wheat was formerly grown in much greater quantity than to-day, prior to 1830 probably in sufficient amount to supply local needs. But the moist climate made it particularly susceptible to fungous diseases, the agricultural periodicals and reports of the first half of the nineteenth century containing frequent references to "blight" and mildew. In order to stimulate production Massachusetts offered a bounty of eight cents a bushel in 1838, without appreciable result. Consequently, as soon as western New York was settled and the drier Genesee Valley was able to ship wheat and flour eastward by way of the Erie canal, the production in New England gradually declined, until to-day the amount of wheat raised in New England is insignificant. Seventy per cent of the wheat in the United States is now grown in regions having less than thirty inches average annual precipitation.

Similarly, cotton can be grown along the Gulf Coast of Florida, Mississippi, and Texas, but its commercial production in this coastal belt has been found to be unprofitable largely because of the heavier autumn rainfall, which not only interferes frequently with the picking of the crop but also may discolor and damage the lint. Cotton in the coastal belt, therefore, has been replaced very largely by winter vegetables, including both white and sweet potatoes, by velvet beans, peanuts, and sub-tropical fruits. Under the severe conditions of competition which characterize modern commercial agriculture, both between regions and between the crops and systems of farming within a region, it requires only a slight natural advantage, or disadvantage, to force one region out of and another into the production of a crop, or one crop off and another crop onto the land.

THE INCREASING IMPORTANCE OF THE TEMPERATURE FACTORS.—The increasing influence of temperature conditions in determining the utilization of the land, as agriculture becomes more highly developed and commercialized, may also be illustrated by the changes that have taken place in the geographic distribution of cotton production, in this instance along the northern border of the Cotton Belt.

Illustrations from the Cotton Belt and the Commercial Apple Areas.—Cotton is the most important "cash" crop, that is, crop grown directly for sale, in the United States; almost none is now consumed on the farm. In the domestic, self-sufficing economy of the colonial and early national eras it was produced as far north as Washington, D. C., and St. Louis, Missouri, and even yet in the isolated valleys of the Kentucky mountains a few acres are grown by the mountaineers to mix with their wool in the weaving of homespun. But as cotton production became commercialized the price declined, and it gradually

became apparent that the cost of production was less where the summer temperature was higher and the growing season longer. So the northern margin of production slowly receded until it stands now at Norfolk, Virginia, and Cairo, Illinois, or, to be more general, at the line of 77° mean summer temperature and 200 days average duration of season from frost to frost. The close correspondence between this length of growing season line and the geographic distribution of cotton acreage is shown in the accompanying map (Fig. 5).

This increasing sensitiveness to geographic conditions with economic progress is further illustrated in the shift in production of the fruits. Apples, for instance, were formerly grown and sold by a large proportion of the farmers in the northern and eastern states, but now the commercial crop is grown mostly in large orchards favorably situated with reference to frost protection, sunshine, and other geographic conditions. Forty per cent of the commercial crop in the years 1918-1920 was grown in the irrigated valleys of the far western states by men who grow little else than apples; and probably fifty per cent more was grown in commercial orchards in small areas in Missouri, western Michigan, western New York, Virginia, and adjacent states, as shown in Figure 6. This geographic specialization in apple production, with coincident decline of the so-called farm orchards, is a development largely of the past thirty years.

The same concentration of production is occurring in practically all the fruit crops and the vegetables, also in the production of butter and cheese, of sugar, tobacco, beans, and, to a less extent, of potatoes. It appears almost inevitable, if there be further development and cheapening of transport facilities, that this trend toward the specialized production of these less important crops and products in certain localities, where climate and soil and accumulated community skill and experience provide peculiarly favorable conditions, will continue; and it is not inconceivable that this development in the United States may result eventually in that geographical differentiation of agricultural production so characteristic of portions of western Europe.

But, on the other hand, if transportation should become more expensive, as seems not unlikely despite the progress of invention, owing to the great increase in cost of coal and labor, the effect would be to encourage local specialization in production, particularly of vegetables and fruits, near the large cities and discourage the development of highly specialized districts of production remote from the markets. In other words, the trend during the past century toward the development of specialized agricultural industries wherever geographic conditions were most favorable, more or less without regard to State or even national boundaries, would be reversed, and each locality would tend to become self-supporting. Geographic differentiation in agricultural production

would still exist, but it would be more local than national or international in character,—more like the agriculture of China.

Illustration from Wisconsin.—The dairy industry in Wisconsin affords a particularly fine illustration of the way in which economic forces compel closer adjustment of types of farming to geographic conditions. Wisconsin now has more dairy cows and probably produces more milk than any other state in the Union. In April 1920 there were 2752 cheese factories in the state, 762 butter factories, 67 condensed and evaporated milk plants, and the total value of dairy products was estimated at 277 million dollars. The development of the dairy industry in this state has been due largely to temperature conditions. First, the cool summer temperatures favor a low bacterial content in the milk and the production of a quality of dairy products, especially cheese, which is not readily obtainable in warmer climates. Secondly, the low temperature and high summer rainfall promote pasturage of high quality which is best utilized by dairy cows, and which also reduces the agricultural work of the summer so far as the feeding of cattle is concerned. Thirdly, for the same reasons, corn can be grown for silage, but not so satisfactorily for grain, and the silage, together with hay, the production of which is favored by the climate, provides excellent winter feed for dairy cattle. Fourthly, dairying affords profitable employment to the rural population during the winter, and thus is peculiarly adapted to the climatic conditions existing in the state.

Within the state, moreover, there has occurred a gegraphic division of territory between the production of butter and of cheese which also has been due largly to the influence of temperature conditions. In 1875, when the dairy industry in Wisconsin was in its infancy, cheese factories and creameries were intermingled in the southeastern portion of the state, to which section they were largely confined at that time. But immediately economic forces began to compel adjustment to geographic conditions, causing the abandonment of cheese production in the warmer southeastern section of the state and the development of the industry on the highlands to the west and along the Lake Michigan shore counties to the northeast. By 1910 all the cheese factories in Kenosha, Racine and Walworth counties had gone out of business, and also all those in the lower eastern portion of Rock county, leaving the creameries to possess the southeastern section of the state (except for city milk production). On the other hand, in the highlands to the west, the thirty-seven cheese factories of 1875 had increased in number to 577 by 1910, while only eight creameries remained in Green, three in Lafayette, and six in Iowa county in this highland district, and most of these were located in the warmer, lower, and

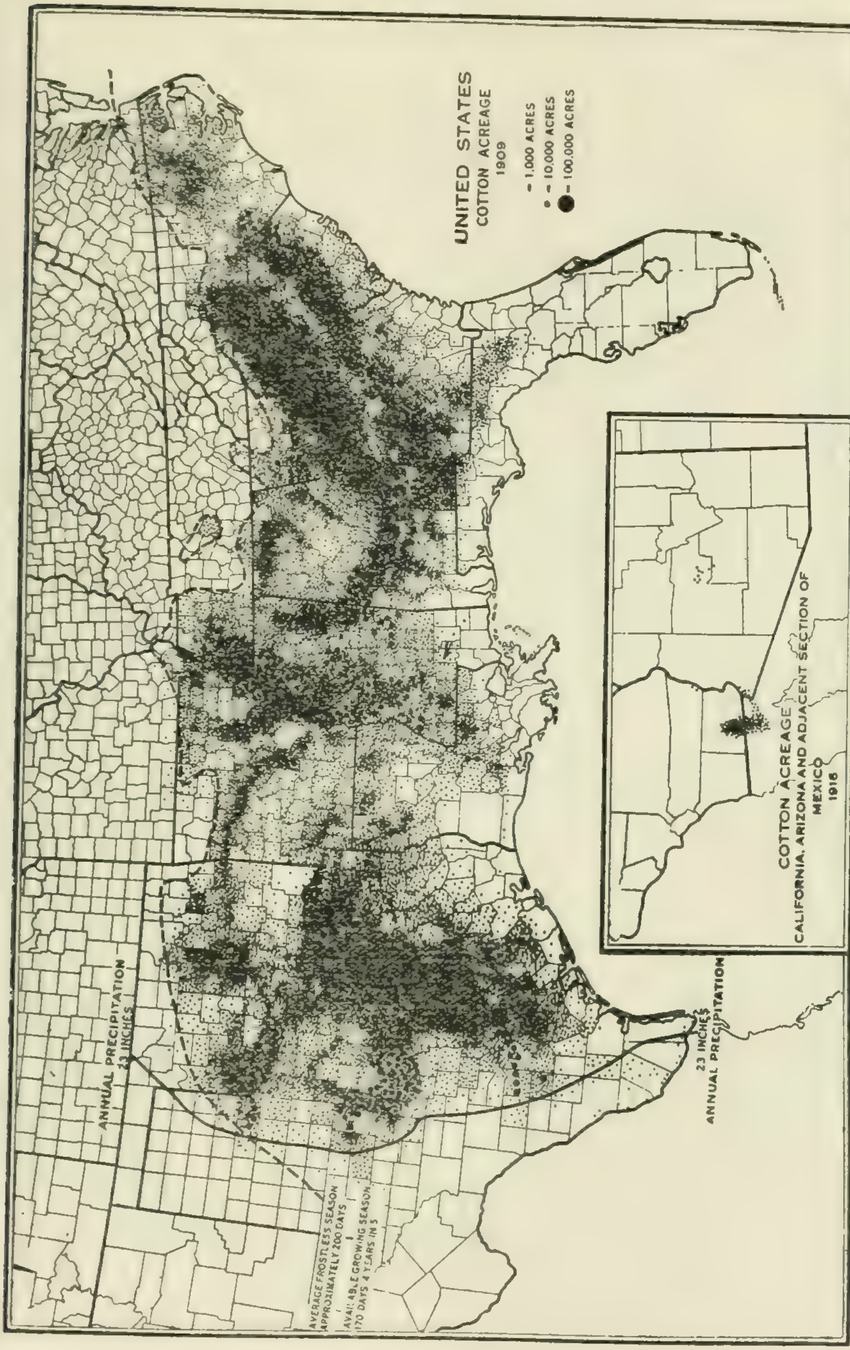

FIG. 5.—The northern limit of commercial cotton production follows closely the average summer temperature line of 77°, and very little cotton is grown where the average season between killing frosts is less than 200 days. The western limit is approximately the line of 23 inches average annual precipitation.

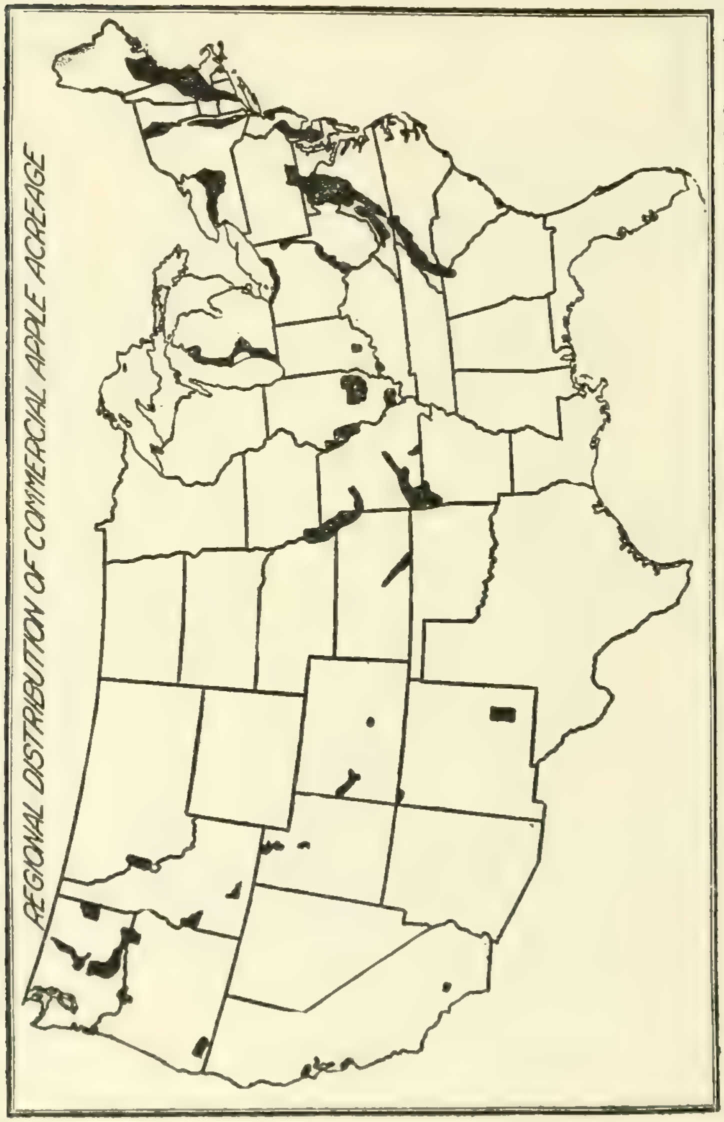

Fig. 6.—It is estimated that over 80 per cent of the commercial apple crop of the United States is produced in the limited areas indicated by the shading.

more sandy river valleys. A similar development of the cheese industry and decline of the butter industry occurred in the cooler Lake Michigan shore counties.[11]

The influence of the temperature factors upon the use of land is, perhaps, more commonly exerted indirectly than directly. Flax, for instance, in the self-sufficing, domestic, agricultural economy of the colonial era, was grown on most farms within its climatic range in order to provide linen for the household; but now its culture is practically confined to the northern Great Plains region, not alone because it finds there a favorable environment, but primarily because it has been excluded from other favorable areas by the competition of crops having more limited climatic requirements, or which for other reasons command a higher price.

This is an important modifying principle to be kept in mind in considering the use of land,—that the crop or farm enterprise most limited by climate, or otherwise, will, ordinarily, have the first choice of land, and will tend to push the less profitable crops beyond the periphery of its climatic limit, or at least keep them off the land necessary to produce a sufficient quantity to meet the effective demand. Thus, cotton excludes corn to a greater or less degree from the best lands of the Cotton Belt, not because corn does not thrive on such lands, but because corn can be grown elsewhere and cotton cannot be with equal success. Likewise corn practically excludes sugar beets from the northern part of the Corn Belt, not because sugar beets do not do well, but because they have a lower temperature requirement and can be grown equally well in other regions where corn does not mature.

The Rising and Falling Margin, or Standard of Utilization, of Land for Crops.—In concluding this discussion of the increasing importance of the physical factors in relation to the use of the land it seems fitting to inquire whether the margin of utilization of land for crops is rising or falling.

First, with reference to topography, the margin has unquestionably been rising and probably it will continue to rise until, and doubtless after, the real wages of agricultural labor have begun to decline. Throughout the United States the rough hill lands that were cleared for crops when population was less mobile and agriculture less commercialized are reverting to pasture or to forest. The declining birth rate, the prospect of a vast increase in importation of sugar and vegetable oils from the tropics, and the rising prices of forest products indicate that possibly for twenty years more rough fields in the hills of New England, the Appalachians, and the Sierra, will be permitted slowly to return to forest or be purchased by the state for such purpose.

[11] For a fuller discussion see Bulletin No. 223. "The Climate of Wisconsin and Its Relation to Agriculture." A. R. Whitson and O. E. Baker.

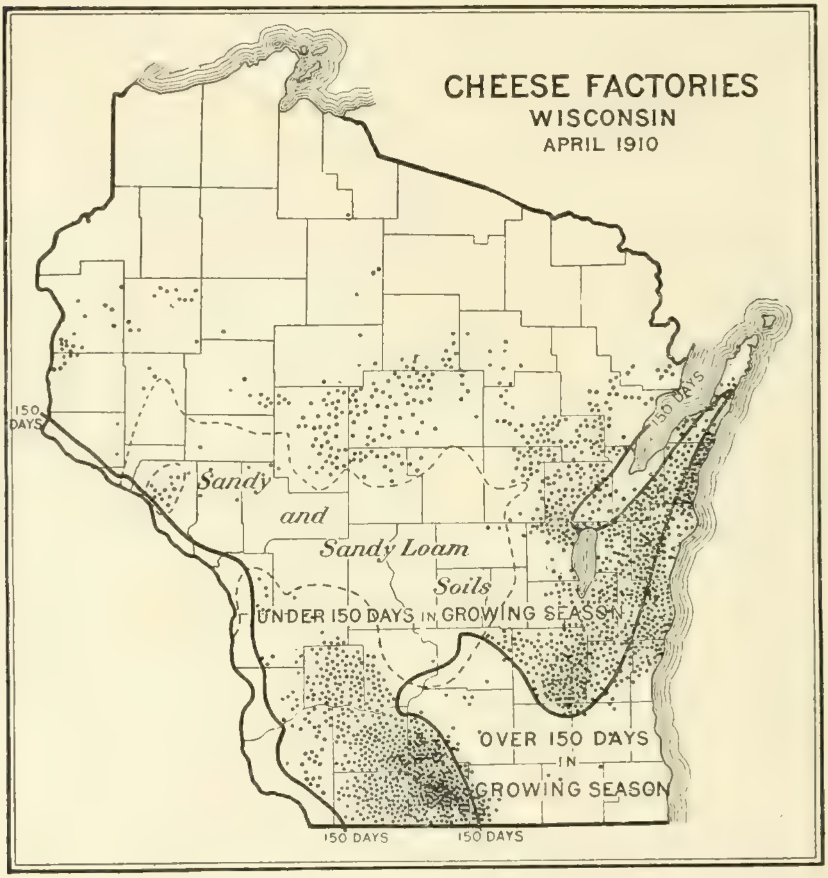

Fig. 7.—Relation of Cheese Districts to Length of Growing Season. Cheese production has developed in those portions of Wisconsin having less than 150 days in the growing season, except in the area of sandy soils. The short, cool season favors summer pasture and cheese production rather than corn and winter butter production, but sandy soils are unfavorable to good pastures. Map from Bulletin No. 223, Wisconsin Agricultural Experiment Station, 1912.

With reference to soils, whether the margin of utilization for crops rises or falls will depend largely on the price of farm products and the cost of ameliorating the adverse physical conditions, particularly the cost of fertilizers. Soil conditions are more susceptible to amelioration, as already pointed out, than the other physical factors, and for this reason the margin of utilization is very responsive to economic forces. In some localities, as in the sandy soils of the Lake states and the stony soils of New England, the margin of utilization is rising; in other localities, as along the South Atlantic Coast, owing largely to the use of fertilizer on crops enjoying a sort of climatic monopoly, and to the excellent transportation facilities by both rail

and water, the margin of utilization is falling. On the whole, the nation is probably at the turning point in the matter of utilization of deficient soils. Agricultural products will come in increasing proportion from the better soils, but the demand will probably be so great as to require the utilization for crops, by means of fertilizers and otherwise, of progressively poorer and poorer soils.

With reference to moisture, undoubtedly crops are being grown in the United States to-day under drier conditions than ever before, owing to economies in labor cost effected by using large scale machinery, to better knowledge of dry-farming processes, and to the introduction of drought resistant crops. With closer adaptation of the system of farming to climatic conditions, a considerable increase in crop acreage is likely to occur in the semi-arid regions. The margin of utilization, in other words, is falling.

Finally, with reference to temperature conditions, considerable readjustment is likely to continue in the inter-relations of crops and of systems of farming; but inasmuch as only in a very small area in the United States are temperature conditions so severe as to preclude the production of such crops as hay, barley, and potatoes, the margin of utilization of land for crops, as contrasted with its utilization for pasture or forest, is little affected by temperature conditions. The margin of utilization for some crops, particularly those whose production can be easily overdone,—cotton, the fruits, vegetables, potatoes, etc.,—is rising, that is, their production is concentrating into areas possessing the most favorable conditions; but other crops, particularly hay, corn, and the large seeded legumes, occupy the land thus released.

Summary.—The margin of utilization of land for crops, therefore, with reference to topography is rising; with reference to soils is probably stationary on the whole, but likely to fall rapidly, unless importation of tropical food products becomes very important; with reference to rainfall is falling; with reference to temperature is practically unaffected. Consequently in certain regions the margin is rising, in other regions, falling; but for the United States as a whole it is apparently falling; that is, agricultural settlement is advancing onto poorer and poorer land. One who has seen the struggles and failures of the young, ambitious, and often capable farmers in the drier portions of the Great Plains, in the sandier sections of the Lake States, or on the leached lands of the South, becomes convinced that the good land is occupied and that land both cheap and fertile no longer exists in the United States. The phenomenal rise in rents and in values of the best lands points to the same conclusion. The waves of population are beating against the barriers of adverse physical conditions all along the shore-line of settlement.

The United States is passing through, if, indeed, it has not already passed, the most significant period in its history. Heretofore the general standard of well-being has been largely maintained, if not improved, by the advance of agriculture onto the fertile lands that occupy the central portion of the continent. Hereafter it can be maintained, only with difficulty, by utilizing the agricultural land, now practically all in farms, more intensively, and with greater attention to the geographic conditions. As the pressure of population upon the agricultural resources of the nation rises, as land becomes scarcer and more valuable, greater and greater care must be exercised in using each kind of land for the purpose most favored by the physical conditions.

With the exhaustion of the virgin stands of timber, the production of lumber and forest products will be placed on an economic basis, and the growing of wood as a crop will enter into competition with other crops, especially for the use of the poorer lands. It is estimated that the present area of forest and woodland, if managed in accordance with forestry principles, could supply, in course of time, the lumber and forest products needs of a population considerably greater than that at present.[12]

With the increase of population meat will increasingly become a luxury and command a price which will compel the use for pasture of much land not suited to crops which is now lying unused or only partly used. Pasture will compete with forest for the use of the less hilly land, and even with crops in the more humid regions; and pasture land, by the use of fertilizers and other means, will be made to carry probably twice its present quota of livestock.

The productivity of crop land cannot be increased to the same extent as forest and pasture lands, but probably the average yields per acre could be increased fifty per cent over those at present, if prices of farm products rose accordingly. The productivity of crop land is, in general, so much greater than that of forest or pasture land that crops will have first choice of the land. Among the crops there are also great differences in productivity, and the more productive crops, such as the vegetables, cotton, corn, alfalfa, will, undoubtedly, to greater extent even than at present, be grown on the better lands. In brief, as population increases, as the prices of agricultural products advance, as agriculture becomes more intensive and commercialized, the use of the land must be fitted to the geographic conditions with greater care and precision.

[12] "Timber Depletion, Lumber Prices, Lumber Exports, and Concentration of Timber Ownership." U. S. Forest Service, Report on Senate Resolution 311, June 1, 1920, p. 39.

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GEOGRAPHIC FACTORS IN THE ANCIENT MEDITERRANEAN GRAIN TRADE

ELLEN CHURCHILL SEMPLE

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Early Importance of the Mediterranean Grain Trade.—The grain trade of the Mediterranean region assumed peculiar importance from very early times. This was due to several causes. Population tended to concentrate on or near the coasts, where maritime conditions encouraged trade and fisheries. There population outgrew the local means of subsistence; for except in a few favored districts, the supply of breadstuffs was inadequate or was subject to fluctuations which made imports necessary. The predominant mountainous relief, thin soils of weathered limestone, the paucity of alluvial valley lands and coastal plains, the practical restriction of grain crops to the winter or rainy season, the elimination of summer crops to compensate for scant harvests from the autumn sowing, the unreliability of the fall and spring rains on which the success of the crops depended, especially in the Eastern Basin,—all combined to make the geographical distribution of grainlands a matter of immense importance in early Mediterranean history.

This was especially true of wheat. According to the ancient writers, wheat required rich, humid earth, preferably deep valley alluvium with plenty of ground water, or fertile volcanic soils retentive of moisture, like that about Naples and Syracuse.[1] Wheat was also fastidious as to its rain supply in the period of germination; this made the exact date for fall sowing a constant problem for the ancient Mediterranean farmer, who saw his hopes of harvest blasted if the

[1] Vergil, Georgic II, 217-224. Columella, II, 9. Theophrastus *Historia Plantarum*, Bk. VIII, ch. IX, 1, 2.

autumn showers held off a few days after he had "consigned his seed to the unwilling earth," as Virgil expresses it. The same thing is true today; the result of the harvest still depends upon the timely advent of the fall and spring rains.[2]

Barley, which was probably indigenous to this region, was far less exacting both as to soil and weather, and therefore better adapted to Mediterranean conditions. Hence it was widely cultivated, from sea level up to 1500 meters (4900 feet). As barley cake and barley broth, it constituted a food staple for the common people, except where the local wheat was ample or the foreign sources of grain accessible to an active merchant marine; for the cost of land carriage was generally prohibitive for this bulky commodity. The price of barley was only one-half or two-thirds that of wheat.[3] This fact reflects the wide distribution of soils and climate suited to barley production, the limited total area of the wheat lands, their uneven distribution which involved heavy marine freight charges to get the product to the best markets, and finally the relatively greater demand for the choicer grains with the advance of civilization. Barley was the earlier and probably the aboriginal cereal in the Mediterranean lands. Wheat is mentioned only three times in the Iliad and six times in the Odyssey a century or more later; but barley in many varieties is frequently mentioned in Homer.[4] The early worship of Demeter at Eleusis in the only fertile alluvial plain of Attica and at Pyrasus in the old lacustrine basin of Thessaly point to the introduction of wheat culture in those districts.[5] The sacrificial bread in religious ceremonies of Greece and Rome was always barley cake, evidence of the primitive use of barley as opposed to wheat. In the time of Cato, however, the cereals cultivated in Italy were chiefly spelt (*far* or *ador*) and wheat, with some barley and millet.[6]

Oats and rye were unsuited to Mediterranean tillage owing to insufficient moisture, though fodder crops of rye were raised in a few northern localities with ampler rainfall and abundant ground water. Millet and panic, which required both heat and moisture, found ideal conditions in the irrigated fields of the Nile valley and the Cilician lowland,[7] where they were grown extensively. In other parts of the Mediterranean basin they were spring crops; were planted at the vernal equinox, throve with but little irrigation, and matured after a short

[2] A. Philippson, *Das Mittelmeergebiet*, p. 167. Leipzig, 1907.

[3] Polybius, Histories, Bk. II, 15; Bk. XXXIV, 7, 8. Boeckh, Public Economy of the Athenians, pp. 128-131. Trans. from the German. London, 1857.

[4] T. D. Seymour, Life in the Homeric Age, p. 328. New York, 1907.

[5] Iliad, II, 695. Hymn to Demeter in the Homeric Hymns.

[6] Mommsen, History of Rome, vol. III, p. 66. New York, 1905.

[7] Xenophon, Anabasis, Bk. I, ch. II, 23.

growing period.[8] Millet and panic kept well and were used for bread or porridge, to a limited degree in ancient Greece,[9] but more extensively in Cisalpine Gaul, because the water supply and occasional summer showers of the Po valley insured abundant millet crops.[10]

Owing to conditions of climate and relief, and to the geological composition of the soils, wheat lands were sparsely distributed and, with a few exceptions, limited in area. Narrow alluvial valleys or lacustrine plains yielded enough wheat for the local demand where the population was small, as in ancient Boeotia, or was satisfied with a predominant barley diet, as in the retarded parts of Greece and Italy. Regions of large wheat production were widely separated, while population tended to pronounced concentration around the big industrial and commercial cities of the Mediterranean littoral, whose advanced culture was associated with fastidious palates demanding wheat as opposed to the widespread plebeian barley. The grain trade was therefore mainly wheat trade. Rarely were generous wheat lands and dense populations contiguous; but markets for the one and breadstuffs for the other were provided by the navigation early developed in this enclosed sea by a fortunate combination of geographic conditions. The districts of big wheat production were Egypt and the Pontic coastlands, which lay outside the Mediterranean climatic region, the Hauran, lowland Cilicia, Thrace, Sicily, parts of Italy, Spain, Numidia and Carthaginian Africa. These raised a sufficient surplus to maintain an export trade, which fluctuated with crop conditions in other parts of the Mediterranean Basin.

Conditions of Navigation Affecting the Grain Trade.—Local production of wheat, however, was everywhere common. It utilized small fertile fields or even mediocre soils, where the seed had to be thinly planted and the harvest was correspondingly meagre. This was due to the fact that the chief importing centers got their foreign wheat from overseas, and that the period of navigation, when such imports could be made, was limited to the four and a half months between early May and the fall equinox. Even this short term was sometimes curtailed by the early advent of autumnal storms. Moreover communication along the sea-lanes was liable to interruption in time of war, as when the Spartan fleet during the Peloponnesian war seized the Boeotian grain ships, laden with Thessalian wheat, as they emerged from the port of Pagasae;[11] or when Sparta in the Peloponnesian

[8] Theophrastus, *De Causis Plantarum*, Bk. IV, ch. VII, 2. *Historia Plantarum*, Bk. VIII, ch. I, 1-4; ch. VII, 3; ch. XI, 1.

[9] Naumann and Partsch, *Physikalische Geographie Griechenlands*, p. 446, Breslau, 1885.

[10] Strabo, Bk. V, ch. I, 12.

[11] Xenophon, Hellenes, Bk. V, ch. IV, 56.

war and Philip in the Macedonian wars intercepted the foreign wheat cargoes bound from various points to Athens; or when Agathocles of Syracuse in 310 B. C. understood to break up the importation of wheat into the rival state of Carthage from Sicily and Sardinia.[12]

Piracy also was a recurrent threat to the wheat trade. This threat was particularly ominous to small islands like Rhodes and Aegina, which constantly took a hand in the suppression of piracy, not only to save their commerce but to supply the home grain markets. Even Rome suffered. For years before Pompey's dictatorship of the Mediterranean in 67 B. C., the depredations of the pirates on the Roman grain ships caused serious scarcity of provisions in the capital and other parts of Italy which relied upon foreign wheat. Circumstances of weather or war, therefore, which cut off the oversea supply of wheat, encouraged the production of home-grown grains to serve in an emergency. Moreover the cost of sea transportation left the local grain a margin of profit, which probably covered the cost of labor and fertilizer necessary to maintain the productivity of the home fields; for the transport vessels were small, the crews were large owing to the need of oarsmen to propel the ship when the course lay in the teeth of the Etesian winds, the voyages were long and slow, and the interest on borrowed capital for such ventures was high, in Athens often 30 per cent.

Grain Trade of the Levantine Sea.—In the Eastern Basin of the Mediterranean, about the Levantine Sea, the grain trade originated at a very early date, owing to the scant and uncertain rainfall. The Nile valley raised irrigated crops of wheat and barley, and, by 1500 B. C., probably durra or black millet[13] far beyond the needs of the local population. Therefore Egyptian wheat figured in the caravan trade with Palestine from patriarchal times during the not infrequent years when drought brought famine or scarcity to Judea and Israel. Palestine raised barley on its infertile limestone highlands; but it seems to have drawn its wheat chiefly from the abundant supplies of the Hauran, the ancient Bashan. This is a high plateau (600-700 meters elevation) east of the upper Jordan and the Lake of Galilee. The west winds from the Mediterranean bring it an average of 400 mm. of rain in winter and early spring, just enough for wheat, supplemented by the considerable dews. In antiquity, judging from numerous ruins of aqueducts and reservoirs, the inhabitants conserved the water draining from the lofty Mount Hauran (1800 meters) on the east, and in dry years distributed it by irrigation canals over the

[12] Diodorus Siculus, Bk. XXI, fragment 12.

[13] A. Erman, Life in Ancient Egypt, p. 434. London, 1894.

tilled land, as the people do to-day.[14] The Hauran is an old volcanic district; its soil consists of disintegrated lava, rich in plant food and retentive of moisture, overlying the limestone which elsewhere in Palestine forms the surface rock.[15] The Hauran was therefore the granary of Syria, probably the source of the wheat which in ancient times was exported from Palestine to Tyre[16] and even to Greece.[17]

The terraced slopes of Phoenicia were better adapted to gardens, vineyards and orchards than to field agriculture. Hence the populous commercial cities of the Lebanon coast drew upon the wheat of the Nile valley in their extensive exchanges with Egypt, and probably also from the wide and well watered alluvial plain of lowland Cilicia, where they seem to have maintained colonies at an early date, till dislodged by the expanding Greeks. Cilicia was famous for its grain fields in the time of Xenophon,[18] and to-day it raises cereals as winter crops on its 1200 square miles of tilled land.[19] Near-by Cyprus, which in antiquity had a reputation for fertility, produced enough wheat on the alluvial floor of its broad intermont valley to supply the local demand in the time of Strabo,[20] and occasionally for export, for Athens bought Cyprian grain.

Grain Trade of the Aegean Coastlands of Asia Minor.—The western front of Asia Minor, which took so active a part in ancient Hellenic life, had grain enough and to spare. The old Aegean folded mountains of Mysia and Hellespontine Phrygia, and the crystalline mass of Lydia and northern Caria are all overlaid with late Tertiary deposits and volcanic outflows, which have contributed important elements of fertility to the silted floors of the subsidence valleys penetrating inland from the embayed coast.[21] The alluvial plains of the Scamander, Caicus, Hermus, Cayster and Meander rivers all had a reputation for fertility in ancient times[22] which made them constant objects of conquest.[23] They yielded wheat crops which were further aided by a favorable climate.[24] The Aegean winds distribute moderate

[14] Ewald Banse, *Die Turkei*, pp. 353, 357, 358. Braunschweig, 1917.

[15] D. G. Hogarth, The Nearer East, pp. 66, 136, 188. London, 1902. E. Huntington, Palestine in Its Transformation, pp. 31, 230-235. Boston, 1911.

[16] I Kings, V, 11. Ezekiel, XXVII, 17.

[17] Theophrastus, *Historia Plantarum*, Bk. VIII, ch. IV, 3. Varro, *Rerum Rusticarum*, I, 44.

[18] Xenophon, Anabasis, II, 23.

[19] E. Banse, *Die Turkei*, p. 176. 1917.

[20] Strabo, XIV, ch. VI, 5.

[21] E. Banse, *Die Turkei*, pp. 124-140. 1917.

[22] Herodotus, I, 149.

[23] Strabo, Bk. VIII, ch. IV, 6; Bk. XII, ch. IV, 4; Bk. XIII, ch. IV, 2, 5, 13.

[24] Vergil, Georgic I, 103. Herodotus I, 142.

rains (500 to 650 mm.) for 60 miles inland.[25] Caria south of the Meander valley floor is a mountainous land of bare crystalline rock, poor thin soil, and a pronounced Mediterranean climate with six months of summer drought. The inhabitants of this coast were forced to seek foreign foodstuffs and to follow commercial vocations;[26] hence the maritime trade of Cnidos and Halicarnassos. The mountain land of Lycia is dissected by gorges, which open on the coast into deltaic flats at the head of protected bays. These small alluvial areas and certain limited lacustrine basins of late Tertiary deposits far up in the mountains furnished the rich " wheat-bearing tilth " of Lycia which Homer praised.[27] It was a self-sufficing land, condemned to isolation, which was reflected in the characteristically detached life and peculiar culture of the people.

The populous Hellenic cities, distributed along the Aegean coast and off-shore islands of Asia Minor, absorbed the surplus grain of the inland states, when they could get it, and reached out overseas for more. They occupied narrow coastal strips, small islands and peninsulas with limited area and mountainous relief. Only Naxos, Samos and Lesbos had a little level land which gave them a reputation for fertility.[28] The island cities at times, by a recognized law of anthropogeography,[29] acquired territory on the opposite coast to extend their land base, as did Samos, Rhodes, Chios and Mytilene.[30] Chios secured a foothold on the Mysian littoral by a shady transaction which gave it Atarneus,[31] market for the grain of the fertile Caicus valley. Mytilene levied on this same Caicus wheatland during the Persian War.[32]

The Hellenic cities, however, were often excluded from the neighboring grain markets by wars waged by the alien inland powers of Asia Minor for the conquest of the Aegean littoral. Hence in their food quest, which was always combined with various commercial enterprises, they turned their ships to the wheat fields of Egypt, the Pontic coastlands of Scythia (Russia), the broad Quaternary plain of eastern Thrace, and the volcanic soils of Sicily. On the coasts of these corn countries they planted colonies as export points for the productive hinterland. A significant connection existed between soil and this

[25] E. Banse, *Die Turkei*, pp. 124-125. 1907.

[26] Ibid., pp. 125, 142.

[27] Iliad, XII, 314-315; XVI, 672-673, 682.

[28] Herodotus, V, 31. Strabo, Bk. XIV, ch. I, 14, 15.

[29] E. C. Semple, Influences of Geographic Environment, pp. 252-253, 444-445. New York, 1911.

[30] Herodotus, III, 39; I, 160. Strabo, XIV, ch. I, 33; ch. II, 2. Thucydides, III, 50; IV, 52.

[31] Herodotus, I, 160; VIII, 106.

[32] Herodotus, VI, 28.

class of settlements. In some cases the Greek colonists helped cultivate the land; in others, they bought the produce of the native population. They also established settlements at strategic points along the sea routes to the grainlands to maintain the line of communication. These way-stations developed a middleman grain trade, owing to the great length of the sea routes and the short duration of the sailing season.

Looking at the evidence, we find that eleven Hellenic cities of the Asia Minor littoral and offshore islands participated in the trading colony of Naucratis on the Canobic arm of the Nile. These cities were Mytilene, Phocaea, Chios, Clazomenae, Teos, Samos, Miletus, Halicarnassos, Cnidos, Rhodes and Pharselis, besides the Greek island city of Aegina.[33] The Aeolian settlements of this coast, whose land enjoyed an exceptional reputation for fertility,[34] had only one representative in the Egyptian enterprise, namely Mytilene, which shared the island of Lesbos with five other city-states. Mytilene was also interested in the Pontic fields, whence it imported wheat.[35] It occupied and fortified Sigeum at the entrance to the Hellespont as early as 600 B. C.,[36] and later built Aenos near the mouth of the Hebrus River[37] (Maritza), which was the Aegean port for the Thracian wheatlands.

The Ionian Miletus, a populous industrial city, took the lead in colonizing the remote Pontic wheatlands by founding Olbia near the confluence of the Bug and Dnieper rivers, and Panticapaeum on the Crimean Bosporus.[38] On the opposite shore of the Strait, Ionian Teos founded Phanagoria. To secure her lines of communication with the Pontic markets, Miletus planted colonies along the Hellespont and Propontis, either alone or assisted by other Ionian towns like Clazomenae, Phocaea and Erythrae.[39] Clazomenae regularly imported its wheat,[40] and doubtless the others did also. On the Thracian shore of the Propontis, Samos founded a colony at Perinthos, which became an export point for Thracian grain. The islands of Rhodes, Chios and Cos were especially active in the Pontic trade, and therefore participated in all Hellenic movements, military or political, to maintain a free passage for merchant ships through the Bosporus and Hellespont.[41] Rhodes turned also to the grain fields of distant Sicily, and

[33] Herodotus, II, 178.
[34] Herodotus, I, 149.
[35] Thucydides, III, 2.
[36] Herodotus, V, 94.
[37] Strabo, Fragment 52.
[38] Strabo, Bk. VII, ch. III, 17; ch. IV, 4.
[39] J. B. Bury, History of Greece, p. 92. London, 1909.
[40] Aristotle, Economics, Bk. II, ch. XVII.
[41] Polybius, IV, 46, 47, 52. Bury, History of Greece, pp. 722-723. 1909.

founded there the colony of Gela on the margin of a fertile plain,[42] about 688 B. C. After the Roman conquest of Sicily, Rhodes secured a permit to export annually 150,000 bushels of Sicilian wheat.[43] It is a significant fact, too, that the Ionian cities of Asia Minor, when threatened with destruction by the Persians, discussed a recurring project to abandon their homes and settle in Sardinia.[44] They were undoubtedly attracted by the security of an island location; but their anticipations of a prosperous future in Sardinia were probably based upon mariners' accounts of the rich valley soil and excellent wheat land of the island.

The Limited Grain Lands of Greece.—Greece was scantily supplied with wheat land, owing to its small area, rugged relief, narrow alluvial valleys, and prevailing infertile soils produced by the weathering of Cretaceous limestones and crystalline rocks. The later Tertiary deposits, whose easily weathered marls made good tillage land, were limited in extent, but they contributed much to the fertility of the valleys of Laconia, Messenia and Elis.[45] The rivers of Greece, being mostly torrents, deposited in their deltaic plains chiefly coarse detritus unfit for tillage. Only a few longer streams, with a well-developed lowland course, afforded the alluvial flats of rich deep soil suitable for wheat fields; yet even these strike the modern traveller as pitiably small. The river plain of Argos, praised by Homer, comprises about 30,000 acres, yet it offered the only local wheat land for three cities,—Argos, Mycenae and Tiryns, besides the seaport of Nauplia. On the other hand, barley, which yielded a fair crop even from poor soil, was widely cultivated, and formed the main diet of the people. Barley bread and barley stew, supplemented by cheese, fruit and wine, constituted the public meals at Sparta in the time of Lycurgus.[46] Wheat bread was a delicacy served as dessert. In early Attica it was eaten only on feast days, till the development of maritime trade made it a commonplace.[47]

Laconia, "lying low among the rifted hills" as Homer described it, was a rugged country suited chiefly for barley culture. Its wheat, which was light in weight and poor in food value,[48] was probably grown only in the narrow valley plain of the Eurotas River. Messenia,

42 Herodotus, VII, 153. A. E. Zimmern, The Greek Commonwealth, p. 66, 1911.

43 Polybius, XXVIII, 2.

44 Herodotus, I, 170; V, 124.

45 Naumann and Partsch, *Physikalische Geographie Griechenlands*, pp. 347-348. Breslau, 1885.

46 Plutarch, Lycurgus, VIII.

47 W. Richter, *Handel und Verkehr der wichtigsten Volker des Mittelmeers im Altertum*, p. 94. Leipzig, 1886.

48 Theophrastus, *Historia Plantarum*, Bk. VIII, ch. IV, 5.

which comprised the broad and fertile Macaria plain at the head of the Messenian Gulf, was accessible to the rain-bearing winds from the west and was watered by numerous streams. Its soil, described by a Spartan poet as "good to plant and good to ear," enjoyed a rare reputation for productivity from very early times.[49] This aroused the cupidity of over-crowded Sparta, which in the seventh century B. C. annexed Messenia after a series of wars, and thereby supplied three thousand young Spartans with new land allotments.[50] Yet wheat remained scarce, and even the local barley crops yielded no margin for times of stress. During the Peloponnesian War, Sparta relied on wheat from Sicily; Athens, to check this trade, sent a fleet in 427 B. C. against Syracuse, the chief export point.[51] During the war of Agesilaus of Sparta against Persia, a flotilla of wheat transports bound from Egypt to Laconia was intercepted in 395 B. C. by the Athenian fleet, then an ally of Persia.[52]

Elis doubtless supplied the local demand for grains from its fertile and fairly ample coastal plain, which was overlaid by late Tertiary marls,[53] enriched by the alluvial deposits of the Peneus and Alpheus Rivers, and adequately watered by the western rains; for the Elians seem to have taken no part in the grain trade. Achaia, on the other hand, which occupied the steep northern escarpment of the Arcadian highland and had only small fragmentary alluvial flats along the Corinthian Gulf, was early driven to colonize Zakynthos, famous for its fertility,[54] and also the small but rich alluvial plains of Sybaris and Metapontum in Southern Italy, where essentially agricultural states developed.[55] The deltaic lowland of the Cratis River at Sybaris gave the largest yield of wheat *per jugerum* in all Italy,[56] and with the Metapontum fields was perhaps the first part of Italy to raise grain for export.[57] Corinth,[58] Megara[59] and Aegina, owing to small area, poor soil and rugged relief, despite careful methods of tillage, were forced to import grain, though little Aegina raised good crops of barley.[60] Therefore Corinth, expanding early, occupied points in southern Acarnania along the Achelous River, whose alluvial plain,

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49 Odyssey, III, 495. Tyrtaeus in Strabo, Bk. VI, ch. III, 3. Euripides in Strabo, Bk. VIII, ch. V, 6. Bury, History of Greece, p. 127. 1909.

50 Ernst Curtius, History of Greece, vol. I, pp. 227-230. New York, 1872.

51 Thuycidides, III, 86.

52 Bury, History of Greece, p. 539. 1909.

53 Naumann and Partsch, *Physikalische Geographie Griechenlands*, p. 348. 1885.

54 Pliny, *Historia Naturalis*, IV, 54.

55 Bury, History of Greece, pp. 103, 105. 1909.

56 Varro, *Rerum Rusticarum*, Bk. I, 44.

57 Mommsen, History of Rome, vol. I, p. 171. New York, 1905.

58 Strabo, Bk. VIII, ch. VI, 23.

59 A Philippson, *Der Peloponnes*, pp. 16-18. Berlin, 1892. Strabo, Bk. IX, ch. I, 6.

60 Herodotus, VII, 147. Strabo, Bk. VIII, ch. VI, 16.

abounding in grain and timber, supplied the most urgent needs of this populous commercial city.[61] Corinth also colonized Potidaea on the Pallene peninsula of southern Macedonia, accessible to a region which produced grain, fruit and timber.[62] Megara secured a colonial foothold near the Sicilian grain fields at Megara Hyblaea, and near those of Thrace by founding Selymbria on the Propontis. She anticipated Miletus in seeking the Pontic wheat markets, for as early as 660 B. C. she insured her access to the Euxine by colonizing Chalcedon and Byzantium, the two warders of the Bosporus. The grain ships which Xerxes in 480 B. C. saw sailing through the Hellespont "on their way to Aegina and the Peloponnesus" were probably destined in part for Megara and Corinth.[63] Aegina's imports from Egypt through the station at Naucratis doubtless included Nile valley wheat, as well as some of the small wares which she hawked about the eastern Mediterranean.

Hellas or Central Greece had a poor reputation among the ancients for fertility,[64] and northern Greece was little better. In Homeric times rugged Epirus, inhabited by the Thesprotians, drew supplies from "the grain fields of Dulichium," probably one of the deposit islands near the mouth of the Achelous River.[65] Wheat lands existed only in small detached districts, as in the Achelous lowland and the valley plain of the Sperchius River, which was considered fertile in Homeric times. The plain of Opuntian Locris and the Crissian plain of rugged Phocis were fertile, but minute. The latter, which would make a good-sized American farm, was dedicated to the shrine of Apollo at Delphi; but it was so rare a bit of tillage land that the neighboring hill-towns of Crissa and Amphissa could not resist the temptation of cultivating it for their own use, and thus brought on the Sacred Wars.[66]

Grain Production in Attica.—Attica had the poorest soil of all Greece. The land was so unproductive that it attracted no invaders, Thucydides tells us.[67] The little Eleusinian plain sacred to Demeter, who here introduced the cultivation of cereals,[68] a few districts in the valley of the Cephissus, and the small alluvial Marathon plain alone could claim fertility. These must have produced Attica's meager wheat crop. According to the Eleusinian inscription of 328 B. C. the average

[61] Strabo, Bk. X, ch. II, 3, 4. E. Curtius, History of Greece, vol. I, p. 290.

[62] Livy, XLV, ch. 30.

[63] Herodotus, VII, 147.

[64] Herodotus, III, 106.

[65] Odyssey, XIV, 335. Strabo, Bk. X, ch. II, 13-19.

[66] Bury, History of Greece, pp. 159, 724-725. 1909.

[67] Thucydides, I, 2, 5.

[68] Homeric Hymns, Hymn to Demeter.

yield of wheat was only one-tenth that of barley.[69] The wheat moreover was light and poor in food value.[70] The barley was excellent; it was the only cereal that could thrive on the porous red soil of weathered limestone and the residuum of weathered crystalline rock, which covered the surface of the Mesogaea or "Midlands" with mediocre soil.[71] A meager average rainfall of 408 millimeters (16 inches), which drops at times to 325 millimeters (13 inches), further reduced the productivity of this ungenerous land.

Athens like Sparta undertook at an early period to despoil some of her neighbors of their best grain land; but these territorial acquisitions were necessarily small. In 506 B. C. she took from Chalcis the fertile Lelantine plain on the neighboring coast of Euboea, and settled there 2000 Athenian colonists to secure her hold; about the same time she seized from Eretria the little deltaic plain of Oropus at the mouth of the Asopus River. This little garden spot had long been a bone of contention between Eretria and Boeotia, whose border it adjoined; and it came to be a chronic cause of enmity between Boeotia and Athens.[72] The small area of these acquisitions emphasize the urgency of Attica's need. The Lelantine wheat fields were vital to Athens as her nearest source of supply. Hence during the Peloponnesian War, the occupation of Decelea by the Spartans in 413 B. C. enabled the invaders to control the road across northern Attica, and thus crippled Athens by cutting its communication with Oropus and the Euboean granary.[73] The great Athenian expansionist Alcibiades[74] urged the expedition for the conquest of Sicily (415 B. C.), on the ground of the abundant wheat, barley and other food-stuffs of the island. Nicias, arguing against the expedition, said:—"The Sicilians have a numerous cavalry and grow their own wheat instead of importing it; in the last two respects they have a great advantage over us."[75] To the Athenian statesmen, the inadequate grain supply was a constant handicap. This weakness had to be counterbalanced by the development of extraordinary strength in other directions. Climate, soil, small area, a long indented coast line, and a commanding central location in the Eastern Basin of the Mediterranean, all combined to force Athens into a brilliant industrial and maritime development. This enabled the state in the age of Pericles to support a population of 250,000, one-half of them slaves, on its scant 700 or

[69] T. D. Seymour, Life in Homeric Greece, p. 328. New York, 1907.

[70] Theophrastus, *Historia Plantarum*, Bk. VIII, ch. IV, 5.

[71] Naumann and Partsch, *Physikalische Geographie Griechenlands*, p. 347.

[72] Bury, History of Greece, pp. 217-218. 1909.

[73] Thucydides, VII, 27, 28; VIII, 95, 96.

[74] Plutarch, Alcibiades, XVI.

[75] Thucydides, VI, 20.

750 square miles of area.[76] Boeckh's estimate of half a million population is excessive, because he grossly overestimates both the fertility and arable area of Attica.[77]

Only two states of Greece, Thessaly and Boeotia, raised an ample supply of wheat; Thessaly alone produced a margin for export.[78] Its extensive lake plains were famous for their fertility from Homeric times.[79] The large area and abundant resources of the land were the geographic foundation of Jason's ambition to make himself master of Greece and the neighboring countries.[80] Generous nature enabled the inhabitants to display a munificent hospitality and develop voracious appetites; "a Thessalian mouthful" was proverbial in Greece.[81] Boeotia was a small state, but it had productive wheat fields and gardens distributed in the lacustrine plains of Lake Copais and Lake Hylica and along the valley of the Cephisus. Fertile soil made the Boeotians a nation of farmers, unenterprising and stolid, but the best fed people of Hellas.[82] The Athenians regarded them with scorn, not unmixed with envy, because of their voracity; and indeed this characteristic made them the butt of the comic writers of Greece. One such humorist, when asked what sort of people the Boeotians were, replied that "they spoke just as vessels might be expected to speak if they had a voice, telling how much each of them could hold."[83]

The Boeotian wheat, according to Theophrastus, was the heaviest and best of the whole Mediterranean region, superior to the Libyan, Pontic, Thracian, Syrian, Egyptian and Sicilian, which in turn was the heaviest of all imported wheats. In proof of his contention, Theophrastus adduced the fact that the Boeotian athletes, who at home ate scarcely three pints of the native wheat a day, easily consumed five pints of Attic wheat when they were staying in Athens.[84] The Athenian wheat therefore seems to have ranked low in food value. The superiority of the Boeotian wheat persisted; when later it entered the grain market of Rome, probably as tribute, it yielded only to the very best Italian product, according to Pliny.[85] There is no evidence however, that the Boeotian grain was exported even across the border into Attica. It was doubtless absorbed by the home market.

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76 Bury, History of Greece, p. 378, note p. 870. 1909.

77 Boeckh, Public Economy of the Athenians, pp. 50-57, 107-114. London, 1857.

78 Xenophon, Hellenes, Bk. V, ch. IV, 5, 6; Bk. VI, ch. I, 11.

79 Iliad, II, 695. Thucydides, I, 2, 3. Strabo, Bk. IX, ch. V, 2, 19.

80 Xenophon, Hellenes, Bk. VI, ch. I, 8-18.

81 Ibid., Bk. VI, ch. I, 3. Athenaeus, X, 12.

82 E. Curtius, History of Greece, Vol. IV, pp. 349-352. New York.

83 Erastosthenes, quoted in Athenaeus, X, 11.

84 Theophrastus, *Historia Plantarum*, Bk. VIII, ch. IV, 5.

85 Pliny, *Historia Naturalis*, XVIII, 7.

EARLY DEVELOPMENT OF THE GREEK GRAIN TRADE.—Poverty of wheat land in Greece necessitated the importation of breadstuffs from the earliest times. Even the most fertile districts, owing to small area, had no surplus for emergencies. These emergencies, moreover, recurred, owing to the variable rainfall and frequent wars between the city-states, with the consequent devastations of the fields in the spring campaigns and interruption to tillage by military service. During the Peloponnesian War, Boeotian Thebes sent ships to Pagasae to buy Thessalian wheat, because for two years its land had remained uncultivated.[86] Preliminary to its revolt from Athens in 428 B. C. Lesbos made extensive importations of grain and other supplies from the Pontic coasts.[87] When the Persian invasion threatened Greece in 480 B. C., Gelon of Syracuse, foreseeing that the Pontic and Egyptian wheat ships bound for Greece would be intercepted by the enemy's fleets, offered to supply Sicilian grain for the entire Hellenic army, and to send a large naval and military force, on condition of his getting the supreme command of the allied forces.[88] This offer points to a long established wheat trade between Sicily and Greece. It also suggests a fact which impresses the investigator in this subject;—namely, that in the ancient Hellenic world wheat was the most important contraband of war.

Constant concern for their breadstuffs, especially wheat, harrassed all the Greek states of the mainland and islands except Boeotia, Thessaly and backward mountain communities like the Arcadian commonwealths, whom nature had long disciplined to an abstemious contentment with the local barley and acorns. This concern stimulated the maritime trade and colonial enterprises of all the distinctly commercial states, whose development was determined by the pull of ready access to the sea and the push of meager tillage land at home.[89] Their governments became the chief *entrepreneurs* in the grain business, because private capital, nervous over the big risks taken by the grain fleets, was limited, and therefore voracious as to profits; transportation facilities were restricted and unreliable; and food supply at any crisis became a national question.[90] Foreign grain markets had to be kept open by reciprocity treaties, and distant grain lands linked with Greece by seaboard colonies. These colonies duplicated the types which emanated from the Hellenic cities of the Asia Minor coast. They were agricultural, like Achean Sybaris and Metapontum on the delta

86 Xenophon, Hellenes, Bk. V, ch. IV, 56.

87 Thucydides, III, 2.

88 Herodotus, VII, 158.

89 E. C. Semple, Influences of Geographic Environment, pp. 15, 268. 1911.

90 W. L. Westerman, Decline of Ancient Culture, Amer. Hist. Review, Vol. XX, p. 736. 1915.

lands of the South Italian littoral, and the AthenianThurii near the earlier Sybaris, where the people "could eat bread without measure;"[91] or strategic way-stations and middlemen ports, like the Athenian Sestos and Cardia on the Hellespont.

The Grain Trade of Athens.—No other Greek state was so dependent upon foreign grain as Athens.[92] Even the Attic farmers relied on it in part, owing to the sterility of their fields.[93] The literature of Athens therefore yields fairly abundant historical material on the extent and control of the grain trade, and shows what probably happened also in other Greek states which carried similar geographical handicaps, but failed to leave behind so ample a record. Grain was brought to the Piraeus from the Pontic coast, especially the Crimea, from eastern Thrace, Syria, Egypt, Libya, Sicily,[94] and occasionally from the island of Cyprus. The Libyan wheat was doubtless the product of Cyrenaica, which had excellent grainland[95] and sufficient rainfall on the Barca plateau (1800 feet), for winter crops; but owing to the semi-arid climate and variable precipitation, the country probably raised a margin of wheat for export only in exceptional years. The same was doubtless true of Cyprus. This island, which normally raised only enough for local consumption, sent grain fleets to Athens in the time of Andocides[96] (468-400 B. C.), probably during the Peloponnesian War, when wheat commanded high prices.

Egyptian wheat was brought to the Piraeus not only by Athenian merchants, but also by foreign grain dealers from Rhodes, Miletus, Phoenicia and Egypt itself.[97] Rhodes and Miletus probably bought wheat beyond their own needs at Naucratis on the Nile, and sold the surplus to their sister state Athens. During a period of scarcity in 445 B. C., the king of Egypt sent a present of 40,000 medimni of wheat to be divided among the Athenian citizens.[98] The dependence of Athens upon Egyptian wheat was marked. After the Macedonian conquest of the Nile valley, Cleomenes, governor of Egypt, worked great hardship against Athens and other Greek states by controlling the export of Egyptian wheat, both as to price and destination. He imposed high export duties and sent the grain to the best market.[99]

91 Bury, History of Greece, p. 380. 1909.

92 Demosthenes' Orations, On the Crown, and Against Leptines. Xenophon, Hellenes, Bk. VI, ch. I, 11. Diodorus Siculus, I, 2.

93 Livy, XLIII, 6.

94 Theophrastus, *Historia Plantarum*, Bk. VIII, ch. IV, 5.

95 Strabo, Bk. XVII, ch. III, 21. Pliny, *Historia Naturalis*, V, 5.

96 Boeckh, Public Economy of the Athenians, p. 76. London, 1857.

97 Ibid. pp. 110, 117.

98 Plutarch, Pericles, 37.

99 Aristotle, Economics, II, 34. Demosthenes, *Cóntre Parmenis, Oeuvres Complettes*, vol. IV, p. 229. Trans. by Abbé Auger, Paris, 1777.

Sicily was a resource for Athens when grain exports from Egypt failed, owing either to a low Nile or to excessive manipulation of the market, as in the case cited. The familiarity of Nicias and Alcibiades with the Sicilian wheat supply in 415 B. C. indicates that Athens, like Sparta, had long imported breadstuffs from that island. The Sicilian wheat was the heaviest brought into Greece, and ranked just below the native Boeotian product.[100] Hellenic grain ships sought the markets not only of the Greek colonies in eastern Sicily, but visited also the Phoenician ports in western Sicily. "The great advantages and profits" which they drew thence[101] can be attributed in part to dealings in grain, for this district exported wheat to Carthage.

The Thracian wheat which Theophrastus was familiar with in Athens probably came chiefly from the Strymon Valley and the neighboring coastal plain as far as the Nessus River. This district was known in ancient as in modern times as fertile and well watered; it was rich in grain fields, forests, and gold mines.[102] Athens seized the coast fortress of Eion near the Strymon mouth from the Persians in 475 B. C.; tempted by the local resources, it made an unsuccessful effort in 465 B. C. to plant a colony at the bridge of the Strymon just above Eion, where thirty years later Pericles established the thriving emporium of Amphipolis.[103] That grain formed one of the exports of Amphipolis is suggested by the fact that about 286 B. C. the king of Paeonia, a country of the upper Strymon and Axius valleys, presented 10,000 Attic medimni of grain as a gift to the Athenian citizens.[104] Other Thracian wheat may have come to Athens from its allies Selymbria and Perinthos, either direct or through the market of Sestos. The East Thracian fields, which were very productive,[105] were probably cultivated by the Hellenized natives who maintained commercial relations with the coasts, because most of the Thracians were engaged in herding in the time of Herodotus.[106]

Importance of the Pontic Markets.—The northern coastlands of the Pontus Euxine became Attica's chief source of wheat, though other Hellenic states were the pioneer traders on those remote shores. The Hellespontine policy of Pisistratus indicates that Athens began her commercial ventures there at the beginning of the sixth century B. C. Her maritime empire established in the age of Pericles drew all the Hellenized shores of the Euxine into her alliance, and opened every

100 Theophrastus, *Historia Plantarum*, Bk. VIII, ch. IV, 3.

101 Herodotus, VII, 158.

102 Pliny, *Historia Naturalis*, XLV, 30. Strabo, Bk. VII, ch. VII, 5; Fragment 36.

103 Bury, History of Greece, pp. 336, 382. 1909.

104 Boeckh, Public Economy of the Athenians, p. 124. 1857.

105 Aristotle, Economics, II, 27.

106 Herodotus, V, 6.

port to her trade. Pericles toured this northern sea to consolidate commercial and political relations by a display of Athenian naval power;[107] for the growth of Athens necessitated increased grain and wood imports from the Pontic shores. In the time of Demosthenes, Leucon, King of the Crimean Bosporus, supplied Athens yearly with 400,000 medimni (600,000 bushels), or nearly half its total annual import of grain.[108] The total import was therefore over 800,000 medimni or 1,200,000 bushels. One year, however, probably in 360 B. C. during the famine of the 105th Olympiad when, as Demosthenes implies, the grain shipments from Theodosia were extraordinarily large, Leucon shipped to Athens 2,100,000 medimni or 3,150,000 bushels.[109]

While the official dealings of Athens were largely with the Crimean grain market of Theodosia, wheat was brought to the Piraeus by foreign merchants from the wide plains of the Dnieper (Borysthenes) and Bug (Hypanis). On the peninsula formed by the confluence of these two rivers stood a temple of Ceres, a seamark on this low coast pointing the way to the grain market of Olbia, which was founded by Miletus and became a wealthy city like the modern Odessa. The Greeks considered the Dnieper district comparable to the Nile valley in productivity.[110] On the Dniester they founded the colony of Tyras,[111] doubtless as a wheat port. The work of tillage was done by Scythian nomads, who became partly Hellenized and settled down to cultivate land for the Greek grain fleets.[112] This Pontic wheat included a hard spring wheat and a soft, light winter wheat. Theophrastus states that both a winter and spring sowing of all grains were made in that country; but as he describes the Pontic wheat in general as very light, importations of winter wheat must have predominated.[113] It therefore came chiefly from the southern and western grain fields of the Pontic littoral, for these are the only sections which to-day have enough snow to blanket the winter fields.

The Pontic coast lands offered profitable fields of trade to the industrial and commercial cities of the Aegean. They were a sparsely populated region of raw production, abounding in the produce of forest, field, pasture and fishing grounds. They yielded not only cereals in abundance, but cattle, hides, wool, salt fish, and timber from the Caucasus. For these the Greek city-states, commanding at home scant wheatlands, scant forests, scant pasturage, exchanged the finer products of the south,—olive oil, wines, potteries, woolen goods and clothing.

107 Plutarch, Pericles, XX.

108 Demosthenes, *Contre Leptines, Oeuvres Complettes*, vol. III, p. 9. Paris, 1777.

109 Strabo, Bk. VII, ch. IV, 6.

110 Herodotus IV, 53, 78. Strabo, Bk. VII, ch. 3, 17.

111 Herodotus, IV, 51.

112 Herodotus, IV, 17, 18.

113 Theophrastus, *Historia Plantarum*, Bk. VIII, IV, 5.

Ships sailed with full cargoes on outbound and homebound voyages, and earned big profits. The Pontic shores, owing to a cold climate and to a backward civilization, afforded better selling markets than Egypt or Sicily; for Sicily, after three centuries of colonization was Hellenized on the eastern side by the time of the Peloponnesian War.

Athenian Control of the Pontic Trade Route.—Forced by her geographic conditions into a precocious industrial and commercial development, Athens early recognized her need of these Pontic markets. About 600 B. C. she seized Mytilene's fortress of Sigeum at the entrance to the Hellespont,[114] probably with the purpose of interfering with Megara's trade in Pontic wheat. In 535 B. C., Pisistratus inaugurated a regular Hellespontine policy aiming at access to the Euxine, and from this policy Athenian statesmen never thereafter deviated. It consisted in augmenting Athenian influence and multiplying Athenian colonies along the Hellespont, Propontis and Bosporus, in order to control this whole strategic passage. The Delian League gave her eventual possession of Lemnos, Imbros and Tenedos, which commanded the Aegean approaches to the Hellespont, and on these islands she rarely loosened her grip. Her line of communication as far as Lemnos was maintained by control of Euboea, which safeguarded the marine Broadway of the Euboean Sound, and by the possession of the islands of Sciathos, Peparethos and rocky Halonnesos. The latter had no value except as an island way-station on the voyage to the Hellespont, though in hostile hands, like those of Philip of Macedon, it threatened the wheat track.[115]

The economic and political life of Athens depended upon her ability to maintain this line of communication; of this fact the state was vividly aware. At the close of the Persian War, Athens sent its fleet to the Hellespont and drove the enemy from Sestos (478 B. C.), which controlled the narrows of the strait, thus clearing the way for future ascendency there.[116] Two years later, when the Spartan Pausanias occupied Byzantium and Sestos, an Athenian fleet under Cimon promptly dislodged the intruder from both positions. After the maritime empire of Athens was established by Pericles, her enemies came to see that her vulnerable spot lay in the straits where her communication with the Pontic grain fields and forests could be most effectually interrupted. Therefore in the latter years of the Peloponnesian War, naval engagements multiplied in the Hellespont, as Athens made a fight for her life. Finally her fleet was wiped out by the Spartans in the battle of Aegospotamos near Sestos in 405 B. C. Ernst Curtius

114 Herodotus, V, 94, 95.

115 Demosthenes, Oration on Halonnesos.

116 Herodotus, IX, 114-118.

surmises that this battle occurred in summer, not later than August, at the peak of the season when the Pontic grain ships were hurrying south, in order to reach their home ports before the September storms should stop navigation.[117] The Spartan Lysander probably selected the critical moment to close the Hellespont, and that with dramatic effect. The Athenian sacred galley escaped from the battle and carried the news to Athens. Xenophon describes the scene which ensued. "At Athens, on the arrival of the Paralus in the night, the tale of their disaster was told; and the lamentations spread from the Piraeus up the long walls unto the city, one man passing on the tidings to another; so that night no man in Athens slept."[118]

Ten years later, when Athens revived and established the Athenian Confederation (395 B. C.) to operate against Sparta, she first secured the alliance of Lemnos and Imbros, island warders of the Hellespont. In 389 B. C. she began to get control over the sea route to the Euxine by drawing into her alliance Samothrace, Lesbos, various Hellespontine cities, Byzantium and Chalcedon, and raised a revenue by imposing tolls on merchandise passing through the Bosporus. Again the straits became the scene of hostilities between Athenians and Spartans, till in 387 B. C. the Athenian fleet was blockaded in the Hellespont and the Pontic grain vessels were cut off from the Aegean.[119] The second Athenian Confederacy (378 B. C.) comprised Byzantium, various Thracian cities, Lesbos, and most of the Euboean towns, all stations on the sea route to the Euxine, besides Rhodes and Chios, who as small island states were vitally interested in the Pontic trade. This time the Spartan fleet did not go so far as the Hellespont, but hovered about Aegina, Andros and Ceos, on the sea approaches to the Piraeus. There they blocked the advance of the grain ships, which had reached the southern end of Euboea, and prevented their rounding Cape Sunium, till the Athenians fitted out an emergency fleet, defeated the Spartan triremes, and brought in the grain to their starving populace.[120] The approaches to the Saronic Gulf offered many strategic points for intercepting the Athenian grain ships. Therefore Athens made Sunium a fortified naval base during the Peloponnesian War to protect this last perilous thirty-mile stretch up to the Piraeus.[121] The outer sea-gate to the Saronic Gulf had the island of Andros and the seaport of Carystus in south Euboea as its keepers. In order to safeguard the strategic passage, therefore, almost the first act of the Delian League was to reduce Carystus in 471 B. C., and force its entry into the con-

117 E. Curtius, History of Greece, vol. III, p. 591, note XI. 1872.

118 Xenophon, Hellenes, Bk. II, ch. II, 3.

119 Bury, History of Greece, pp. 546, 550-552.

120 Xenophon, Hellenes, Bk. V, ch. IV, 60-61.

121 Thucydides, VIII, 4.

federation.[122] When Athens converted the League into an empire, she took the further precaution of settling cleruchies or out-colonists in Andros to secure the loyalty of that island (447 B. C.).[123]

Whoever fought Athens had to strike at her overseas grain trade. Therefore her next rival, Thebes, was forced out of her normal character as a land power and assumed the novel rôle of a sea power; built a hundred triremes, and sent them to the Propontis to prey upon the Pontic grain ships (364 B. C.). While Athens from her base at Sestos endeavored to defend these, the Theban admiral adopted the obvious policy of stirring up the Hellespontine cities of the Chersonnesus against Athens, and alarming King Cotys of Thrace with predictions of Athenian conquests. Cotys seized Sestos and nearly the whole Chersonnesus in 360 B. C. His death soon after and the decline of Thebes enabled Athens to recover control of the Hellespont in 357 B. C., when she again drew Euboea into her alliance.[124] Thus, with her old possessions Lemnos and Imbros, she restored the security of the grain track from the Propontis to the Piraeus, and fortified herself for her next big struggle.

Philip of Macedon was the next rival to Athens. The chief actor in the drama changes, but not the scenes or the dramatic episodes. These recur with historical monotony due to the same controlling geographic conditions. There was the same old struggle for the control of the Bosporus, the Hellespont and the wheat emporiums of the Thracian coast,—Byzantium, Selymbria, and Perinthos. Macedon, like Thebes, was forced to become a naval power. She let loose her triremes to capture Athenian wheat transports in the north Aegean and to harry Lemnos, Imbros, and Euboea. There the Macedonian forces seized Eretria and fortified Oreus at the northern end of the island, in order to dominate the stormy and dangerous entrance into the Euboean Sound.[125] Philip's land campaigns aimed at the conquest of Thrace, from Byzantium to the tip of the Chersonnesus, where Athens was most vulnerable. He endeavored to conquer Athens in Thrace, as Napoleon endeavored to conquer England in Egypt. The arguments of Demosthenes to arouse Athens to the gravity of the danger paralleled those used in the British Parliament for the continuance of the French war. Demosthenes, enumerating his provisions for Athens' safety, gives a digest of the geography and the strategy of the war. By the recovery of lost Euboea he protected the Attic seaboard and the grain track through the Euboean Sound. Effecting the release of Byzantium, the Chersonnesus and Halonnesos from Mace-

122 Bury, History of Greece, p. 337. 1909.

123 Plutarch, Pericles XI.

124 Bury, History of Greece, pp. 615-617, 682-683. 1909.

125 Demosthenes, Oration on the Chersonnesus, and First Philippic.

donian dominion, he opened the Hellespont and Bosporus for the passage of the Pontic grain ships, and provided for their conveyance along a friendly coast all the way to the Piraeus. He persistently exhorted the citizens to expand and strengthen the navy, with which to guard these overseas connections.[126]

THE TASKS OF THE ATHENIAN NAVY.—Athens was the Britain of the ancient Mediterranean. Its navy alone guaranteed the full loaf of bread. Fleets had to police the Pontic wheat track against the Caucasus pirates, and suppress other sea-robbers who recurrently infested the routes to Egypt and Sicily. A strong navy was necessary to check sporadic depredations on the merchant ships by rival powers even in time of peace. Chalcedon, embarrassed by an empty treasury, once utilized its location on the Bosporus to plunder some vessels going north into the Euxine,[127] doubtless loaded with manufactured goods with which to pay for the return cargo of wheat and fish. While Philip of Macedon was besieging Selymbria in eastern Thrace, his fleet captured twenty Athenian grain ships passing through the Propontis to the Hellespont *en route* to Lemnos, because the Macedonian admiral suspected that the supplies were meant for the besieged city.[128] Again early in the reign of Alexander the Great, Pontic ships were arbitrarily seized by the Macedonians and held up at Tenedos, though freedom of the seas and security of ships against seizure had been pledged by Alexander's recent treaty with Greece. Athens' prompt equipment of a large naval fleet led to the release of the captured vessels.[129]

In time of war, naval convoys attended not only the wheat fleets of Athens but those of any member of the Athenian Confederacy. For this protection an annual tribute was paid.[130] Hostile attacks were not limited to the mere seizure of food vessels. When Demetrius of Macedon was besieging Athens about 300 B. C., he captured a wheat transport bound for the Piraeus, and hanged the captain together with the pilot. This treatment so terrified the merchants that they stayed away and let Athens starve till she surrendered to Demetrius.[131]

COMMERCIAL TREATIES AND ALLIANCES.—At all times the gloved hand of diplomacy aided the mailed fist of the navy. In the age of Pericles, and again in the time of Demosthenes, the international policy of Athens was dominated by the economic interests of the State. In the Euxine Athens held the friendship of the Greek towns by giving

[126] Demosthenes, Oration on the Crown.

[127] Aristotle, Economics, II, 11.

[128] Demosthenes, Oration on the Crown, and the Letter of Philip.

[129] Demosthenes, Treaty of Alexander.

[130] Demosthenes, Oration on the Chersonnesus.

[131] Plutarch, Demetrius, XXXIII.

them support against barbarian attacks. With the reigning house of the Cimmerian Bosporus she maintained close relations based upon reciprocity of trade. Leucon, prince of Panticapaeum from 393 to 353 B. C., exempted Attic ships from the export duty, allowed them to purchase grain ahead of other ships, and fixed a market for them in the excellent port of Theodosia near the Crimean wheat fields.[132] Athens convinced him that she was his best customer, and conferred honors upon him. She also cultivated friendship with the powers of the Thracian Bosporus and Propontis; with the Persian satrap of Hellespontine Phrygia, who by reason of geographical location could imperil or police the southern strait; with the barbarian kings of eastern Thrace; and with the free cities of Byzantium and Perinthos,[133] who not only occupied strategic positions, but were themselves wheat emporiums.

Byzantium grew rich on her Pontic trade. It was an obvious policy for the cities of the Propontis and straits to accumulate grain, either by direct importation from the Euxine or by the levy of port dues and Bosporus tolls, paid in kind,[134] on passing ships; they could then resell it to merchants who were unwilling to make the long voyage to the Crimea, or who arrived near the end of the sailing season and wished to return home before the autumn storms. Thus we read that Heraclea, located on the Thracian coast north of the Chersonnesus, sent forty ships to the Crimean Bosporus to buy wheat and other supplies.[135] Sestos was called in Athens " the wheat-bin of the Piraeus,"[136] a term applicable only to a grain emporium. Its strategic location at the narrows of the Hellespont made it not only a base for military control, but also like Byzantium a natural toll station which Athens sometimes used for collecting transit dues, levied in kind, if we may judge from Leucon's export taxes on the Pontic wheat. Athens showed persistent friendship for Egypt and Cyprus by assistance rendered to these states when revolting against Persian dominion. Her motive may have been partly her old hostility to the Great King, but partly also her need of Egyptian and Cyprian grain.

Government Control of the Athenian Grain Market.—The grain market of the Athenian Agora, despite all government measures to insure a steady supply of wheat and barley, was sensitive to every political movement in Scythia and Thrace, to every disturbance in the towns of the Bosporus and Hellespont. Prices fluctuated according to

132 Demosthenes, *Cóntre Leptines, Oeuvres Complettes*, vol. III, pp. 19-20. Paris, 1777.

133 Demosthenes, Letters of Byzantium and Perinthos in the Oration on the Crown.

134 Xenophon, Hellenes, Bk. I, ch. I, 22. Polybius, IV, 44, 46.

135 Aristotle, Economics, II, 9.

136 Aristotle, Rhetoric, III, 10.

the seasons, as these were favorable or unfavorable to crops and to navigation; they fluctuated as importations increased or diminished, as export duties were raised or lowered in the grain emporiums of the Mediterranean, and as the markets were cornered both within and without Attica and prices arbitrarily raised. War and piracy always made the grain business in the Piraeus feverish. The fluctuations, however, were not excessive except during a siege or sudden threat of war. In the time of Pericles and Socrates, the medimnus of prepared barley cost normally two drachmae or 34.2 cents, and wheat was probably a third more. In 396 B. C. wheat sold for three drachmae or 51.3 cents, and fifty years later in the time of Demosthenes for five drachmae or 85.5 cents.[137] Prices in other Greek states were about the same. At Lampsacus the normal price for a medimnus of wheat in Aristotle's time was four drachmae or 68.4 cents, but this was arbitrarily advanced by the State to six drachmae, or $1.02 at a threat of war, doubtless as a hint for conservation.[138]

The cheapest and best market in which the Athenians could buy was that of the Crimean Bosporus. There excellent rates were given even in time of scarcity. At Olbia on the Dnieper estuary, prices were variously two, four and eight drachmae or 34.2 cents to $1.37 in the first or second century B. C., but they must have been lower in the fifth and fourth centuries B. C. Prices in Egypt were low, reflecting the fertile soil, large arable area, cheap labor, and the relative certainty of harvest under irrigation tillage. In the time of the Ptolemies the normal price for spelt and wheat was about two drachmae or 34.2 cents the medimnus, and in times of scarcity it increased hardly threefold. Shortly after the founding of Alexandria, however, under the satrap Cleomenes, the wholesale price of wheat rose to ten drachmae or $1.71 in a time of scarcity. Sicilian grain was doubtless cheap prior to the Roman conquest of the island. In 74 B. C., the price of wheat there was fixed at an equivalent of 91.2 cents and barley at 45.6 cents the medimnus.[139]

The vicissitudes of the grain trade, due largely to geographic conditions, necessitated governmental control. Even Egypt found it necessary in years of reduced crops to prevent exports, either by direct inhibition or by imposition of enormous export duties.[140] Selymbria, though located in a wheat-growing district of Thrace, prohibited grain exports in time of scarcity.[141] Athens during the Peloponnesian War employed her control of the Bosporus and Hellespont to allow no grain

137 Boeckh, Public Economy of the Athenians, pp. 128-129. 1857. Demosthenes, Oration against Phormion.

138 Aristotle, Economics, II, 8.

139 Boeckh, Public Economy of the Athenians, pp. 130-132.

140 Aristotle, Economics, II, 34.

141 Ibid., II, 17.

exports from the Euxine or Byzantium, except by express permission as to the destination and annual amount.[142] She thus waged an economic war against her ill-fed enemies like Corinth, Megara and Sparta, and used her command of the Pontic grain as a means to hold the allegiance of her restless insular allies, like Rhodes, Cos, Chios and Lesbos.

At all times the grain trade of the Piraeus was closely controlled, as was also the sale of lumber and ship supplies; otherwise the commerce of Athens was free. The exportation of native grain from Attica was prohibited by law. Furthermore, two-thirds of every cargo of foreign grain entering an Attic port had to remain in the country. No inhabitants of Attica, whether native or alien residents, might transport grain to any other but Attic ports; nor might they so much as loan money on the security of a vessel, unless such vessel should return to Athens with a cargo of grain or other commodities. The object of these measures was to compel importations of foreign grain. Furthermore Athens appointed certain officials who kept account of the imported grain, and saw to it that two-thirds of the supply should be brought to the city from the ports. She provided public storehouses for the state-owned grain, and also for the stock of private dealers. Government commissioners purchased grain for the state, while yet others received and measured it.[143] Thus a reserve was at hand in time of emergency, to be sold to the populace at a moderate figure and to stabilize prices. Probably some of it was given to the citizens. Measures were also adopted to prevent dealers from cornering the market. Retailers might sell only at the advance of one obolus, or about three cents on the cost price of a medimnus, though in time of dearth they ran up the prices and sold at six times the legal profit. Eager to profit by every fluctuation in the market, the grain dealers spread alarming rumors to send up the price of wheat, saying that the grain ships had been wrecked in the Euxine or captured at sea by the Spartans, that commercial treaties had been violated and the grain ports closed against Attic merchantmen, with the result that the nervous populace was willing to buy at any price. To curb these enemies within the state, Athens imposed a death penalty for any effort to establish a grain monopoly.[144] The free foreign dealers regularly bought grain in the cheapest market and sold in the highest, and with this purpose they scoured the Aegean, the Euxine and the Sicilian coasts.[145] Athens made every effort to attract them to the Piraeus

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142 Boeckh, Public Economy of the Athenians, p. 78.

143 Ibid., 78--78, 114-116, 121-123.

144 Lysias, *Cóntre les Commercans de Blé, Oeuvres Complettes*, pp. 304-305. Trans. by Abbé Auger, Paris, 1783.

145 Xenophon, *Oeconomicus*, XX, 27-28.

market; this rich and populous state was in a position to pay well for the needed breadstuffs, but it encouraged competitive selling.

It is reasonable to suppose that other states, possessing similar geographic conditions to those of Attica, and therefore compelled to import overseas grain, adopted similar foreign and domestic policies to maintain a balance of breadstuffs and population. The abundant literature of Athens enables us to reconstruct in considerable detail the constant efforts of the state to fill its grain-bins. Megara, located astride of the Isthmus of Corinth with a port on each side, maintained connection with the Sicilian fields as well as with the Pontic wheat lands, as indicated by her colonies both in Sicily and on the Bosporus. Corinth early in the eighth century B. C. established trade relations westward with Syracuse and other Sicilian wheat markets. Mountainous Achaia, located on the marine highway of the Corinthian Gulf[146] and having easy access to the west, imported grain from Sicily and doubtless also from her Italian colonies in the fertile plains of Sybaris and Croton. The island states of the Aegean, like Rhodes, Chios and Cos, seem to have relied chiefly on the Pontic grain. They therefore rushed to the support of Athens whenever the Euxine connection was jeopardized. Their interests were identical, and therefore they were nearly always members of the various Athenian confederacies. After the decline of Athens, Rhodes became the chief maritime power of the Aegean. In 228 B. C., we find her heading all the states interested in the Pontic trade in a war against Byzantium, which had got astride of the Bosporus by the acquisition of territory on the Asiatic side, and was levying a toll on all goods brought from the Pontus.[147] As Rhodes and her island confederates assisted Athens and Byzantium against the expanding power of Philip of Macedon, in 340 B. C., in his effort to control the straits, so in 201 B. C. the Rhodian League joined the King of Pergamos and the Romans to prevent Philip V. from attaining a like purpose.[148]

Wheat Production in Western Mediterranean Lands.—In the lands of the Western Mediterranean, geographic conditions were more favorable to wheat culture than in the Eastern Basin, apart from the Pontic and Egyptian fields, which lay outside the Mediterranean climatic region. The rainfall was in general greater, more reliable, and lasted longer. Hence the farmers' crops were less jeopardized by failure of the autumn and spring rains. Tertiary and Quaternary plains, though no larger, were more evenly distributed. In Sicily and parts of Italy disintegrated lava, tufa, and volcanic ash lent

146 Theophrastus, *Historia Plantarum*, Bk. VIII, ch. IV, 5.

147 Polybius, IV, 39, 46, 47, 50.

148 Mommsen, History of Rome, vol. II, p. 411. 1905.

exuberance to the fertility of the soil, and enabled it to retain the moisture necessary for the maturity of the crop during the dry period before the harvest. Sicily was an important granary from very ancient times, and produced wheat that almost equalled the Boeotian grain in nutritive quality. Theophrastus attributed the heavy crops to the frequent spring showers of Sicily.[149] Strabo states that its wheat, honey and saffron surpassed that of Italy.[150] Its grain exports went to Greece certainly at the beginning of the 5th century B. C., and probably earlier. During the time of Agathocles of Syracuse, about 310 B. C., Carthage imported wheat and other provisions from Sicily and Sardinia, securing this traffic by her control of the sea. Agathocles, at war with his Punic neighbor, planned to break up this grain trade and equipped a fleet for the purpose.[151]

EARLY ROMAN GRAIN TRADE.—Rome imported Sicilian wheat from the beginning of the Republic. Ordinarily the fertile plains of the lower Tiber and Anio sufficed for the agricultural communities which constituted the ancient Latin League and the early Roman state; but during periods of drought which destroyed the harvests, or of sustained war, which interrupted tillage and devastated the growing crops, importations of wheat and spelt were necessary. Frequently these came from the fertile volcanic region about the Bay of Naples. The moist black earth of Capua and the famous Phlegraean fields about Cumae were considered standard wheat lands by the ancients,[152] and their choice product could be readily transported by sea along the coast to the Tiber mouth. Rome's nearer neighbors, the Hernici of the broad and fertile Trerus River valley, and the Volscii of the upper Liris valley and the Latium coastal plain, possessed good wheat land, and at times they seem to have sold grain to Rome; but they were victims of Roman wars of expansion and therefore generally refused to sell to their ambitious neighbor in her hour of need.[153] Rome therefore often drew upon the abundant grain resources of Etruria, whence wheat could be transported either down the Tiber or along the coast. Etruria is an old volcanic region of rich heavy soil. Its streams drain hills overlaid with trachyte, tufa and basalt, and deposit in the valley plains soil rich in potash, soda and phosphoric acid,—all important articles of plant food.[154] Pliny considered the wheat of Clusium, grown in the lake-strewn basin of the upper Clanis River (Chiana), the best

149 Theophrastus, *Historia Plantarum*, Bk. VIII, ch. IV, 4; ch. VI, 6.

150 Strabo, Bk. VI, ch. II, 7.

151 Diodorus, Siculus, XXI, fragment 12.

152 Vergil, Georgic II, 217-224. Columella, II, 9. Strabo, Bk. V, ch. IV, 3, 4, 8.

153 Livy, II, 34.

154 W. Deecke, Italy, pp. 64, 96, 376. New York, 1904.

in the world. It weighed twenty-five per cent more than Boeotian wheat.[155]

In the early interstate grain trade of Italy, Rome figures as a frequent importer. During a protracted period of famine in 490 and 489 B. C., it purchased grain all along the Etruscan and Campanian coasts and in Sicily. Etruscan grain was also brought down the Tiber, probably from the rich Clusium fields.[156] In 474 B. C., during a scarcity due to a prolonged war with Veii, Rome imported wheat from Campania;[157] in 437 B. C., when evidently a general drought had reduced the harvests, she "sent out embassies by land and sea to all the neighboring states to purchase grain, with little result except that a small quantity was procured in Etruria."[158] In 409 and 408 B. C. Rome was forced by famine and pestilence to import grain from Etruria, the upper Tiber cities and Greek Sicily. She could get none from Campania because the fertile district of Capua and Cumae had just been conquered by the mountain Samnites, who refused to aid their rival neighbor.[159] Etruria continued to be the chief Italian source of supply[160] until Rome established her naval power sufficiently to ensure importations of overseas wheat. The importance of this nearby reliable supply of Etruscan wheat may be inferred from the fact that in 210 B. C., when the grain fields of Campania were in Hannibal's hands, and those of Sicily had been devastated by five years of continual war, Rome's granaries were so depleted that a medimnus of Sicilian wheat sold in Rome for the high price of 15 denarii, or $2.56.[161] At this juncture Rome renewed an old alliance with Egypt, and secured the support of its grain ships to feed Italy and the legions.[162] On the restoration of peace in Sicily, she made extraordinary efforts to revive agriculture in the island for the sake of the wheat.

Territorial Expansion and the Roman Grain Trade.—This second Punic War, which gave Rome command of the sea, demonstrated to the government the possibility of maintaining Italy and her army by wheat from Sicily and Egypt. Then followed a disastrous competition between the small Italian farms and the vast slave estates in the rich wheat lands of Sicily, Sardinia, Numidia, Carthaginian Africa, and the Guadalquivir valley of Spain.[163] Field agriculture in

155 Pliny, *Historia Naturalis*, XVIII, 7.

156 Livy, II, 34.

157 Livy, II, 52.

158 Livy, IV, 12, 13.

159 Livy, IV, 52.

160 Livy, XXVIII, 45.

161 Polybius, IX, 44.

162 Mommsen, History of Rome, vol. II, p. 315. 1905.

163 Strabo, Bk. III, ch. II, 6; Bk. V, ch. II, 7. Pliny, *Historia Naturalis*, XVIII, 10.

Italy declined as the country was flooded with foreign grain. Sea transportation of wheat from Sicily and Sardinia was as cheap as land transportation from Etruria and Campania. The extensive alluvial plain of the Po valley, especially Gallia Transpadana, yielded fine wheat in large quantities,[164] but it was too far from the capital to compete with Sicilian and Sardinian grain. Hence in 150 B. C. wheat sold there for four oboli or twelve cents the medimnus, and barley for two oboli or six cents,[165] owing to lack of a market. The farmers found it more profitable to feed their grain to hogs, fattening the mast-fed pigs till they rivalled modern Berkshires and exporting the hams and bacon to Rome.[166] Meanwhile Sicilian and Sardinian wheat sometimes sold in Rome for the freight charge.[167] The conquest of Spain, especially the fertile Guadalquivir valley, in the Second Punic War placed the Iberian grain at the disposal of Rome. Even in 203 B. C. the government drew wheat both from Spain and Sicily to supply Scipio's army in Africa, while that army, immediately after landing on Carthaginian soil, gathered in the grain from the broad and productive fields of the Bagradas River valley.[168] At the close of the war Rome was selling its citizens Spanish and African wheat at 12 to 24 asses (20 to 40 cents) a medimnus.[169] It procured the grain by tribute and purchase. The Roman army fighting in Macedonia in 170 B. C. was supplied by Carthage with 250,000 bushels of wheat and 125,000 bushels of barley. Numidia sent it an equal amount of wheat which the Roman government bought.[170]

After the annexation of Carthaginian and Numidian Africa and the conquest of Egypt, both the tribute and purchase grain increased in amount, in proportion to the productive area and fertility of these countries. In the time of Augustus, Egypt furnished one-third of the grain consumed by Rome, Africa another third, while Sicily, Sardinia, Spanish Baetica, and Italy's own reduced yield supplied the final third. The grain of Egypt and Africa was so vital to Italy and the Imperial City that these countries became the key to the control of Rome itself. Conquest of either one was equivalent to the conquest of Italy, a fact that was not lost upon the later adventurous aspirants to the throne of the Caesars.[171]

The immense area of the Roman Empire, which finally included all the Mediterranean wheat lands, was the politico-geographical factor

164 Pliny, *Historia Naturalis*, XVIII, 7.
165 Polybius, II, 165.
166 Strabo, Bk. V, ch. I, 12.
167 Livy, XXX, 38.
168 Livy, XXX, 3.
169 Mommsen, History of Rome, vol. III, p. 76. 1905.
170 Livy, XLIII, 6; XLV, 13.
171 Mommsen, Provinces of the Roman Empire, vol. II, pp. 260, 366-7. 1887.

which stimulated grain importations into Italy and discouraged native agriculture. Italy's focal location in the Mediterranean Sea was a second geographic factor operating to the same end. It facilitated maritime movements of grain from all the big areas of production and on a scale impossible in a land empire in ancient times. Italy's location was comparable to that of the Attic peninsula in the Eastern Basin, and was conducive to similar economic effects. The maintenance of these systematic importations depended upon the security of the sea-ways between the wheat countries and the Roman markets, and therefore upon the efficiency of the navy. The decline of Roman sea power from 102 to 67 B. C. fatally weakened the marine police. Pirates so infested the grain tracks that between 75 and 67 B. C. imports ceased, and the price of wheat at Rome soared to 120 sestertii or $4.65 the medimnus, or about ten times the market price in Sicily.[172] Therefore when Pompey was appointed dictator of the sea in 67 B. C., his first act was to clear the waters about Sicily, Sardinia and Africa, in order to restore the movement of wheat from those provinces to Italy; his next was to suppress the Cilician pirates, who issued from their convenient lairs along the Taurus Mountain littoral and infested the wheat route from Egypt passing their doors.[173]

Imperial Rome and Athens owing to quite different causes were both singularly dependent upon overseas grain lands. The vulnerable spot of Athens' sea empire lay in the Hellespont; that of Rome's land empire lay in Africa and Egypt. While Athens was constantly fighting rival Greek commonwealths, whom she was powerless to conquer because of her small land base and the nature-made individualism of the Greek states, Rome eliminated her foreign enemies by the *pax Romana*, but left sea pirates who captured her grain ships, and political pirates who seized the imperial throne by possessing themselves of her chief grain lands. There was perhaps never a time that ancient Italy could not have fed itself from its home fields, except in the rare years of drought. There was never a time that Athens could have fed itself, unless it established a maritime power supported by some measure of political power, as evinced in the various Athenian confederacies. Rome's expansion aimed always at more territory; an imperial parasite, she lived off of the newly acquired lands as Athens never lived off of Euboea or Thrace or Crimea. Therefore Rome's grain lands became a bludgeon in the hands of candidates for the imperial throne.

172 Cicero, Verres, 92, 214.

173 E. C. Semple, The Pirate Coasts of the Mediterranean, Geog. Rev., vol. II, pp. 134-151. New York, 1916.

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THE CLIMATE OF SOUTHEASTERN IDAHO[1]

GEORGE ROGERS MANSFIELD

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INTRODUCTION.—A study of the climate of southeastern Idaho was made by the writer as a phase of the U. S. Geological Survey's investigation of the Idaho phosphate field. The results are deemed of sufficient interest to warrant separate publication.

As shown in the accompanying map (Fig. 1), the region extends northward along the Wyoming line from lat. 42° to about lat. 43° 30′ and westward from about long. 111° to about long. 112° 30′. It includes the actual southeast corner of Idaho and a narrow strip of western Wyoming as far east as the base of the Salt River Range. The region is generally mountainous with ranges that trend northward or northwesterly, but it contains a number of broad, intermontane valleys, such as Bear Lake Valley, and to the northwest it descends to the Snake River Plain. The altitudes of the larger valleys range from 4500 to about 6200 feet and the mountains rise 2000 to 3000 feet higher.

Climatological data for 16 stations within the region here described are given in publications of the United States Weather Bureau.[2] At some of these stations records have been kept continuously for periods as great as ten or twenty years. At others the records have been discontinued after longer or shorter intervals. At still others the records have been kept for so short a time that they have as yet little value in climatological studies. There is also considerable variation in the degree of completeness of the records at the several stations.

In order to show the variety of climatic conditions in different parts of the region some of the more important records of all these stations are given in tables below. In these tables the records summarized in the first publication cited above, which include data for the years up to and including 1914, have been corrected to the close of the year 1919, by interpolation of data from the other volumes cited.

[1] Published by permission of the Director of the United States Geological Survey.

[2] Summary of climatology of the United States by sections: U. S. Dept. Agriculture, Weather Bureau Bull., W, secs. 22 and 23, 1912; also Climatological data of the United States by sections, vols. 1-6, 1914-1919 incl.

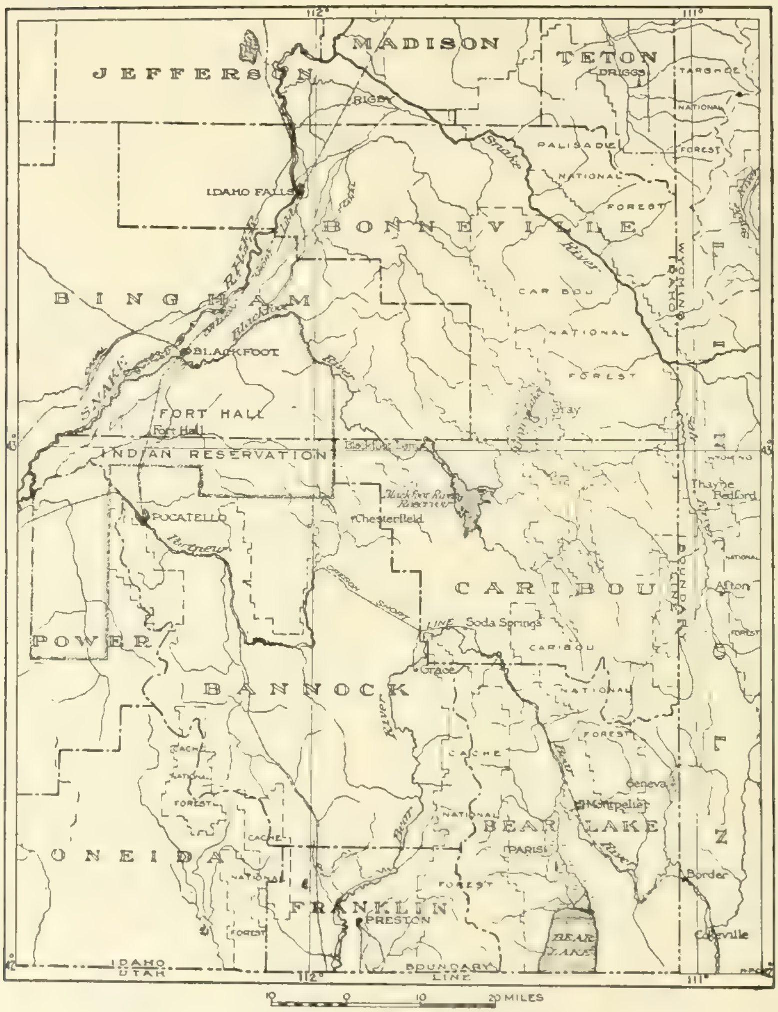

Fig. 1.—Map of the region showing location of stations

From these later volumes also the data for the new stations have been compiled. The location of the stations is shown in Fig. 1.

Description of Tables.—Table 1 gives the names, locations, and elevations of the several stations, together with the lengths and limiting dates of their records. Table 2 gives the monthly and annual mean precipitation at each station in inches and hundredths. Table 3 gives the average number of rainy days (days with .01 inch or more of precipitation) at each station for each month and for the year. Table 4 shows the average snowfall (unmelted) in inches. Tables 5, 6, and 7 give respectively the highest, lowest, and mean temperature recorded

TABLE 1—CLIMATOLOGICAL STATIONS OF THE REGION

Station	Location	Elevation Feet	Length of Record	
			Years	Dates
Afton......	Lincoln Co., Wyo., on Swift Creek at the east side of Star Valley (6 miles wide) and at the west base of the Salt River Range. Afton quadrangle.	6,200	17	1903–1919 (Some months missing)
Bedford....	Lincoln Co., Wyo., near Strawberry Creek in Lower Star Valley a mile and a half from the west base of the Salt River Range. Afton quadrangle.	6,200	21	1899–1919 (A few months missing)
Blackfoot Dam...	Caribou Co., Ida., near north end of Blackfoot River Reservoir on Blackfoot lava field. Low mountains rise at distances of 1½ to 3 miles. Cranes Flat quadrangle.	6,150 (6,129 U.S.G.S. B.M. at dam.)	10	1915–1919 (Some years missing)
Border.....	Lincoln Co., Wyo., on state line in valley of Bear River about ¼ mile from north slope of Bear River Plateau and about ½ mile from the river. Montpelier quadrangle.	6,073 (U.S.G.S. B.M. at Border.)	18	1902–1919
Chesterfield	Bannock Co., Ida., on Twenty-four Mile Creek at the northeastern side of Portneuf Valley (4 miles or more wide) and at the west base of the Chesterfield Range. Portneuf quadrangle	5,454 (U.S.G.S. B.M.)	22	1915–1919 (Some years missing)
Cokeville...	Lincoln Co., Wyo., in the valley of Bear River near the rocky gap by which Smith's Fork enters the valley.	6,204	10	1910–1919
Fort Hall...	Bingham Co., Ida., on Ross Fork of Portneuf River and on the Gibson terrace east of Snake River in the Fort Hall Indian Reservation.	4,500	5	1915–1919
Geneva....	Bear Lake Co., Ida., in the northern part of Thomas Fork Valley. Mountains rise on either side at distances of 1 to 1½ miles. Montpelier quadrangle.	6,171 (U.S.G.S. B.M.)	6	1915–1916 (Records very incomplete)

Table 1—Climatological Stations of the Region—Continued

Station	Location	Elevation Feet	Length of Record	
			Years	Dates
Grace......	Bannock Co., Ida., in the northern part of Gentile Valley, near the west base of the Bear River Range.	5,400	12	1915–1919 (Records very incomplete)
Grays Lake.	Bonneville Co., Ida., on the east side of Grays Lake and at the west base of the Caribou Range.	6,300	3	1917–1919 (Some months missing)
Idaho Falls.	Bonneville Co., Ida., on Snake River, about 3 miles west of the foothills of the Caribou Range in the Snake River lava plain.	4,742	25	1880–1919 (Some years missing)
Montpelier.	Bear Lake Co., Ida., at the mouth of Montpelier Canyon on the east side of Bear Lake Valley, there about 5 miles wide, and at the west base of the Preuss Range, Montpelier quadrangle.	5,943 (U.S.G.S. B.M. 5,963)	5	1915–1919
Paris.......	Bear Lake Co., Ida., on the west side of Bear Lake Valley, there about 9 miles wide, and immediately east of the foothills of the Bear River Range, Montpelier quadrangle.	5,946 (U.S.G.S. B.M. 5,966)	16	1893–1908 (Some months missing)
Pocatello...	Bannock Co., Ida., in the lower part of the canyon of Portneuf River with high hills to northeast and southwest and canyon extending from southeast to northwest.	4,483	20	1899–1919 (Some years missing)
Pocatello Nursery.	Bannock Co., Ida., detailed location not stated.	5,396	12	1908–1919 (Records very incomplete, several years missing)
Thayne....	Lincoln Co., Wyo., in Lower Star Valley about 4 miles west of the Salt River Range and 1 mile east of the Caribou Range. Freedom and Afton quadrangles.	5,900	8	1899–1906

TABLE 2. PRECIPITATION AT 15 STATIONS IN WYOMING AND IDAHO: MONTHLY AND ANNUAL MEANS

(in inches and hundredths)

Station	Av. length of available record years	Jan.		Feb.		Mar.		Apr.		May		June		July		Aug.		Sept.		Oct.		Nov.		Dec.		Annual	
		yrs	in.	yrs	in.	yrs	in.	yrs	in.	yrs	in.	yrs	in.	yrs	in.	yrs	in.	yrs	in.	yrs	in.	yrs	in.	yrs	in.	Years complete	in.
Afton	14.0	13	1.50	15	1.52	15	1.69	16	1.40	15	2.29	14	1.29	14	1.26	14	0.98	13	1.47	12	1.90	13	0.72	15	1.25	13	17.27
Bedford	19.3	20	2.02	20	1.74	17	1.64	20	1.42	20	2.32	18	1.60	20	0.94	20	1.08	19	1.56	17	1.71	19	1.16	21	1.40	19	18.59
Blackfoot Dam	4.8	5	1.15	4	2.03	4	1.30	5	1.03	5	1.79	5	0.80	5	0.99	5	0.50	5	1.68	5	1.58	5	0.91	5	1.60	4	15.36
Border	17.9	18	1.38	18	1.41	18	1.19	18	1.46	18	1.45	17	1.26	18	0.56	18	0.82	18	1.13	18	1.16	18	0.81	18	0.70	17	13.33
Chesterfield	3.4	4	0.96	4	1.63	4	1.14	4	1.65	3	2.32	4	0.79	4	1.32	4	0.40	3	1.26	3	0.79	2	1.08	2	1.31	0	14.65
Cokeville	10.0	10	1.10	10	1.08	10	0.93	10	1.23	10	1.16	10	1.04	9	0.89	9	0.56	10	1.42	11	1.18	10	0.84	11	0.65	8	12.08
Fort Hall	4.9	4	0.50	5	0.81	5	1.13	5	0.80	5	1.65	5	0.41	5	0.58	5	0.45	5	1.12	5	1.05	5	0.56	5	0.51	4	9.57
Geneva	2.0	2	1.47	2	0.60	2	0.90	2	0.35	2	1.93	2	0.74	2	0.36	2	0.42	2	1.61	2	0.27	2	0.90	2	1.14	2	10.69
Grace	4.3	5	0.62	4	1.11	5	0.76	5	0.95	5	1.82	3	0.37	5	0.72	5	0.70	5	0.74	4	1.02	3	0.87	3	1.60	2	11.28
Grays Lake	2.1	3	1.58	2	1.38	2	1.52	1	0.97	2	2.88	3	0.49	3	1.21	2	0.51	1	1.85	1	1.13	2	1.22	3	1.12	0	15.86
Idaho Falls	18.3	18	1.56	18	1.27	19	1.80	19	1.08	19	1.73	19	1.16	18	0.58	18	0.76	18	0.77	18	0.98	17	0.94	19	1.16	15	13.79
Montpelier	4.8	5	0.89	5	1.98	5	1.08	5	1.28	5	1.39	5	0.65	5	0.56	5	0.58	5	1.28	5	1.36	4	1.03	4	0.74	4	12.82
Paris	12.6	14	1.27	11	0.87	12	1.55	11	1.42	14	1.36	13	0.71	12	0.60	13	0.85	12	0.89	13	0.97	12	0.91	14	1.03	8	12.43
Pocatello	14.5	14	1.09	14	1.35	14	1.76	14	1.35	14	1.65	14	0.85	15	0.48	15	0.58	15	0.71	15	0.92	15	0.64	15	1.08	14	12.46
Thayne	6.8	7	1.70	7	1.54	8	1.74	8	1.27	8	2.63	7	1.06	6	0.86	7	0.88	7	0.77	6	1.29	5	1.07	6	1.14	4	15.95
Region	9.3	10	1.36	9	1.41	9	1.46	10	1.28	10	1.75	9	1.05	9	0.77	10	0.77	9	1.14	9	1.23	9	0.88	10	1.08	7.6	14.27

TABLE 3. AVERAGE NUMBER OF DAYS WITH .01 INCH OR MORE OF PRECIPITATION

Station	Av. length of available record years	Jan.		Feb.		Mar.		Apr.		May		June		July		Aug.		Sept.		Oct.		Nov.		Dec.		Annual	
		yrs	days	yrs	days	yrs	days	yrs	days	yrs	days	yrs	days	yrs	days	yrs	days	yrs	days	yrs	days	yrs	days	yrs	days	Years complete	days
Afton	14.8	14	8	15	9	16	11	16	8	15	11	14	7	15	5	15	5	15	6	15	7	14	6	14	8	11	91
Bedford	19.9	20	10	20	9	19	10	20	8	20	10	20	7	20	5	20	5	20	6	20	7	20	6	20	8	18	91
Blackfoot Dam	4.8	5	8	4	9	4	6	5	5	5	8	5	3	5	5	5	2	4	5	5	4	5	5	5	6	3	66
Border	17.9	18	7	18	8	18	6	18	6	18	7	17	6	18	6	18	6	18	7	18	7	18	6	18	7	15	79
Chesterfield	3.2	4	8	3	7	4	7	4	7	3	10	3	4	4	6	3	2	3	5	3	2	2	7	2	8	0	73
Cokeville	9.4	10	8	10	8	9	7	9	6	10	8	10	5	9	6	9	3	9	3	9	6	9	6	10	5	7	71
Fort Hall	4.9	4	7	5	8	5	8	5	7	5	8	5	4	5	6	5	4	5	6	5	5	5	6	5	7	4	76
Geneva	1.9	2	6	2	8	2	7	2	4	2	7	2	6	2	4	2	4	1	6	2	4	2	5	2	5	1	66
Grace	4.0	5	8	4	8	5	6	5	5	4	7	3	2	5	4	4	4	4	6	4	6	3	6	2	9	1	71
Grays Lake	1.7	3	5	2	6	2	4	1	3	..	..	3	3	2	3	2	4	1	7	..	..	2	4	2	6	0	..
Idaho Falls	8.7	8	10	8	7	9	8	9	6	9	11	9	6	9	5	9	6	9	5	9	6	8	5	8	7	7	82
Montpelier	4.8	5	10	5	10	5	8	5	8	5	9	4	3	5	4	5	2	5	6	5	7	4	7	4	6	3	80
Paris	13.0	13	9	13	7	13	8	13	6	13	7	13	5	13	3	13	4	13	4	13	5	13	6	13	8	13	72
Pocatello	14.0	14	11	14	10	14	11	14	9	14	10	14	6	14	5	14	6	14	4	14	6	14	7	14	10	14	95
Thayne	7.0	7	12	7	12	7	14	7	10	7	12	7	7	7	8	7	5	7	5	7	8	7	10	7	10	7	113
Region	8.7	9	9	9	8	9	9	9	7	9	9	9	6	9	5	9	5	9	5	9	6	8	6	8	8	6.9	84

TABLE 4. AVERAGE SNOWFALL (UNMELTED: INCHES)

Station	Av. length of available record years	Jan.		Feb.		Mar.		Apr.		May		June		July		Aug.		Sept.		Oct.		Nov.		Dec.		Annual	
		yrs	in.	yrs	in.	yrs	in	yrs	in.	yrs	in.	yrs	in.	yrs	in.	yrs	in.	yrs	in.	yrs	in.	yrs	in.	yrs	in.	Years complete	in.
Afton	14.8	14	17.0	16	16.5	16	12.6	16	7.6	14	3.2	13	1.7	15	0	16	0	15	1.1	14	4.7	14	5.9	14	11.7	11	82.0
Bedford	19.9	20	21.2	20	23.9	19	14.3	20	6.5	20	3.3	20	0.4	20	0	20	0	20	0.9	20	5.2	20	8.8	20	15.1	19	99.6
Blackfoot Dam	4.5	4	15.8	4	19.5	3	13.5	5	2.0	5	2.5	5	T	5	0	5	0	4	0.1	4	4.9	5	8.6	5	14.2	1	81.1
Border	13.4	14	16.7	13	14.6	12	18.6	13	6.3	13	2.1	14	T	14	T	14	0	15	1.4	13	2.4	13	4.6	13	4.6	11	71.3
Chesterfield	3.3	4	14.5	4	18.8	4	5.2	4	1.5	3	0.3	4	T	4	0	3	0	3	T	3	T	2	6.0	2	12.6	0	58.9
Cokeville	9.5	10	13.8	10	13.9	9	9.8	9	6.3	9	2.2	10	0.4	9	0	9	0	10	1.5	10	5.2	9	7.1	10	8.1	8	68.3
Fort Hall	5.0	5	4.3	5	8.3	5	6.4	5	0.8	5	0.2	5	T	5	0	5	0	5	0	5	0.6	5	2.0	5	5.5	5	28.1
Geneva	1.9	2	19.5	2	15.0	2	6.5	2	2.5	2	7.0	2	2.5	2	0	2	0	1	0	2	0.5	2	10.5	2	12.0	1	76.0
Grace	3.8	4	5.4	4	9.4	4	5.0	5	1.7	3	0.5	3	0.2	5	0	4	0	4	0	4	1.0	3	3.2	2	6.2	1	32.6
Grays Lake	2.8	3	20.5	2	22.0	2	17.0	1	4.0	2	1.8	3	T	3	0	2	0	1	0	..	...	2	8.8	3	14.2	0	....
Idaho Falls	4.4	3	10.3	3	9.6	4	2.4	5	0.8	5	0.6	5	0	5	0	5	0	5	T	5	2.3	4	2.4	4	7.2	2	35.0
Montpelier	4.7	5	17.0	5	24.4	4	4.0	5	5.0	5	1.9	4	1.6	5	0	5	0	5	T	5	4.1	4	9.1	4	6.8	2	73.9
Pocatello	5.0	5	12.7	5	13.1	5	8.1	5	3.0	5	0.1	5	T	5	0	5	0	5	T	5	0.8	5	2.5	5	9.6	5	49.9
Thayne	7.0	7	15.0	7	12.3	7	10.4	7	4.5	7	3.4	7	T	7	0	7	0	7	1.5	7	2.6	7	5.5	7	10.3	7	65.5
Region	7.1	7	15.8	7	15.8	7	11.3	7	4.9	7	2.3	7	0.5	7	T	7	0	7	0.8	7	3.5	7	6.2	7	10.3	5	70.8

TABLE 5. HIGHEST TEMPERATURE—MONTHLY AND ANNUAL

Station	Av length of available record: years	Jan		Feb.		Mar.		Apr.		May		June		July		Aug.		Sept.		Oct.		Nov.		Dec.		The Period	
		yrs	deg	yrs	deg.	yrs	deg.	yrs	deg.	yrs	deg.	yrs	deg.	yrs	deg.	yrs	deg.	yrs	deg.	yrs	deg.	yrs	deg.	yrs	deg.	Years Complete	Degrees
Afton	14.9	16	70	16	55	16	69	16	81	15	86	14	92	15	96	14	94	14	91	15	82	13	76	15	59	13	96
Bedford	19.9	20	49	20	58	20	59	20	76	20	93	20	93	20	97	20	93	20	88	19	82	20	66	20	51	19	97
Blackfoot Dam	4.7	5	50	5	47	4	57	5	80	5	78	5	94	5	96	5	94	4	89	4	78	4	64	5	55	4	96
Border	17.9	18	48	18	50	18	67	18	79	18	88	17	94	18	96	18	96	18	88	18	84	18	67	18	58	17	96
Chesterfield	3.5	4	56	5	45	5	64	4	78	3	76	4	94	4	94	3	95	3	89	2	77	2	72	3	54	1	95
Cokeville	9.9	10	53	10	63	10	64	10	79	10	90	10	96	9	96	10	93	10	89	10	75	10	64	10	51	9	96
Fort Hall	5.0	5	57	5	52	5	69	5	81	5	94	5	100	5	98	5	100	5	91	5	83	5	70	5	58	5	100
Grace	4.8	5	68	4	50	5	70	5	84	5	95	4	100	5	103	5	101	5	98	5	90	5	69	4	63	4	103
Grays Lake	2.3	3	48	2	44	3	62	2	62	2	77	3	94	3	103	2	90	1	88	1	75	2	66	3	54	0	103
Idaho Falls	9.0	9	51	9	57	9	68	9	81	9	95	9	98	9	98	9	97	9	90	9	82	9	70	9	58	9	98
Montpelier	4.9	5	52	5	51	5	61	5	76	5	92	5	98	5	100	5	100	5	89	5	79	5	67	4	53	4	100
Paris	15.0	15	61	15	63	15	64	15	79	15	88	15	97	15	97	15	97	15	92	15	87	15	78	15	59	15	97
Pocatello	14.0	14	57	14	56	14	68	14	80	14	94	14	99	14	102	14	99	14	92	14	82	14	69	14	57	14	102
Thayne	7.0	7	47	7	55	7	56	7	74	7	81	7	92	7	96	7	91	7	87	7	78	7	65	7	48	7	96
Region mean	.	.	55.1		55.3	..	64.6	..	78.7	..	89.2	..	95.4	..	97.6	..	95.6	..	90.0	..	82.1	..	69.3	..	55.6	..	97.6
absolute	9.5	10	70	10	63	10	70	10	84	10	95	9	100	10	103	9	101	9	98	9	90	9	78	9	63	8.6	103

TABLE 6. LOWEST TEMPERATURE—MONTHLY AND ANNUAL

Station	Av. length of available record years	Jan.		Feb.		Mar.		Apr.		May		June		July		Aug.		Sept.		Oct.		Nov.		Dec.		The Period	
		yrs	deg.	yrs	deg.	yrs	deg.	yrs	deg.	yrs	deg.	yrs	deg.	yrs	deg.	yrs	deg.	yrs	deg.	yrs	deg.	yrs	deg.	yrs	deg.	Years Complete	Degrees
Afton	15.1	16	-47	16	-41	16	-23	16	- 5	15	4	14	22	15	18	14	16	15	15	15	- 2	13	-26	15	-44	13	-47
Bedford	19.9	20	-34	20	-46	20	-27	20	- 6	20	13	20	20	20	24	20	22	20	16	19	3	20	-26	20	-30	19	-46
Blackfoot Dam	4.9	5	-35	5	-38	4	-27	5	- 7	5	13	5	22	5	31	5	28	5	17	5	- 4	5	-25	5	-42	4	-42
Border	17.9	18	-37	18	-48	18	-36	18	- 1	18	12	17	19	18	27	18	20	18	13	18	-18	18	-29	18	-36	17	-48
Chesterfield	3.5	4	-38	5	-29	4	-25	4	- 5	3	4	4	25	4	26	3	21	3	12	2	9	3	-16	3	-29	2	-38
Cokeville	9.9	10	-38	10	-44	10	-38	10	- 6	10	8	10	18	9	26	10	21	10	13	10	-12	10	-20	10	-33	9	-44
Fort Hall	4.9	5	-26	5	-13	4	8	5	13	5	17	5	27	5	34	5	33	5	24	5	4	5	-12	5	-28	4	-28
Grace	4.6	5	-22	4	-12	5	-14	5	6	5	21	4	29	5	32	5	32	5	25	4	10	4	- 7	4	-23	2	-23
Grays Lake	2.3	3	42	3	-21	3	-31	2	- 3	2	12	3	25	3	25	2	29	1	25	1	- 8	2	- 8	3	-40	1	-42
Idaho Falls	9.0	9	-31	9	-32	9	-26	9	13	9	20	9	28	9	36	9	31	9	23	9	1	9	-11	9	-23	9	-32
Montpelier	5.0	5	-32	5	-24	5	-25	5	0	5	13	5	23	5	24	5	30	5	17	5	0	5	-20	5	-26	5	-32
Paris	15.0	15	-33	15	-35	15	-23	15	0	15	15	15	15	15	21	15	24	15	15	15	3	15	-13	15	-19	15	-35
Pocatello	14.0	14	-19	14	-20	14	-12	14	17	14	24	14	33	14	38	14	33	14	21	14	3	14	- 3	14	-13	14	-20
Thayne	7.0	7	-26	7	-47	7	-23	7	2	7	11	7	21	7	24	7	19	7	13	7	7	7	- 1	7	-30	7	-47
Region mean	....	..	-33.5	..	-36.3	..	-24.7	..	1.0	..	13.5	..	22.3	.	26.8	..	25.2	.	16.7	.	- 0.7	.	-17.7		-29.3	..	-40.4
absolute	9.5	10	-47	10	-48	10	-38	10	- 7	10	4	9	15	10	18	9	16	9	12	9	-18	9	-29	10	-44	8.6	-48.0

TABLE 7. MEAN TEMPERATURES—MONTHLY AND ANNUAL

Station	Av length of available record: years (from monthly records)	Jan.		Feb.		Mar.		Apr.		May		June		July		Aug.		Sept.		Oct.		Nov.		Dec.		Annual	
		yrs	deg.	yrs	deg.	yrs	deg.	yrs	deg.	yrs	deg.	yrs	deg.	yrs	deg.	yrs	deg.	yrs	deg.	yrs	deg.	yrs	deg.	yrs	deg.	Years Complete	Degrees
Afton	14.0	15	16.4	15	18.9	15	27.5	15	35.7	14	46.9	13	55.7	14	61.0	13	60.0	14	52.6	14	43.8	12	32.8	14	18.0	12	39.2
Bedford	19.8	20	17.4	20	19.6	19	27.9	20	37.2	20	46.1	20	53.2	20	59.8	20	58.6	20	50.9	19	41.2	20	30.2	20	17.5	18	38.2
Blackfoot Dam	4.7	5	14.4	5	18.1	4	25.3	5	37.7	5	46.7	5	56.6	5	62.9	5	58.2	4	51.2	4	41.4	4	27.5	5	16.9	4	37.8
Border	19.9	20	12.8	20	14.6	20	25.1	20	38.7	20	47.2	19	56.0	20	63.1	20	60.9	20	51.6	20	40.9	20	28.5	20	13.9	20	37.8
Chesterfield	3.3	3	19.1	5	20.8	4	28.2	4	41.0	3	45.3	4	54.7	4	61.9	3	60.0	3	51.2	2	42.2	2	32.4	3	23.9	..	....
Cokeville	9.8	10	15.5	10	18.4	10	27.5	10	38.2	10	46.3	10	55.3	9	61.1	9	58.3	10	49.9	10	37.6	10	26.7	10	14.9	9	37.7
Fort Hall	4.8	5	20.2	4	29.4	4	39.1	5	45.6	5	51.2	5	61.7	5	69.6	5	66.9	5	58.6	5	45.7	5	33.3	5	25.3	4	45.4
Grace	4.7	5	21.7	4	27.0	5	34.0	5	44.7	5	51.0	4	61.6	5	69.8	5	66.8	5	59.7	4	46.0	4	32.1	5	26.6	2	45.2
Grays Lake	1.4	3	14.0	2	19.0	3	24.9	2	34.3	2	42.3	3	55.0	3	61.7	2	58.9	1	52.9	1	39.4	2	31.8	3	30.7	..	....
Idaho Falls	19.0	19	18.3	19	22.1	19	32.4	19	44.4	19	51.5	19	59.3	19	68.0	19	67.1	19	57.7	19	45.0	19	31.7	19	22.5	19	43.3
Montpelier	4.8	5	16.3	5	21.0	5	28.0	5	41.2	5	47.9	5	59.1	5	66.0	5	63.7	5	54.8	5	42.3	4	31.4	4	22.6	4	41.4
Paris	15.0	15	19.7	15	19.7	15	27.4	15	39.6	15	49.2	15	55.8	15	63.5	15	62.9	15	55.0	15	44.0	15	33.1	15	21.0	15	40.9
Pocatello	19.0	14	24.6	14	28.9	14	38.7	14	46.7	14	54.3	14	64.0	14	71.5	14	70.3	14	60.8	14	48.2	14	36.2	14	28.3	14	47.6
Thayne	7.0	7	18.7	7	18.9	7	28.0	7	37.7	7	47.5	7	54.3	7	60.3	7	58.7	7	50.1	7	40.9	7	31.9	7	18.3	7	38.8
Region	10.5	10	17.7	10	21.2	10	29.4	10	40.2	10	48.6	10	57.1	10	64.1	10	61.9	10	54.1	10	43.0	10	31.3	10	20.1	10.7	40.8

TABLE 8. PREVAILING WIND DIRECTION

Station	Av. length of available record: years (from monthly record)	Jan.		Feb.		Mar.		Apr.		May		June		July		Aug.		Sept.		Oct.		Nov.		Dec.		Annual	
		yrs	wind	yrs	wind	yrs	wind	yrs	wind	yrs	wind	yrs	wind	yrs	wind	yrs	wind	yrs	wind	yrs	wind	yrs	wind	yrs	wind	Years Complete	Wind
Afton	4.1	5	N	5	W	5	S	5	SW	4	S	3	S	4	SW	3	S	4	S	4	S	3	S	4	S	4	S
Bedford	19.9	20	W	20	W	20	W	20	W	20	W	20	W	20	W	20	W	20	W	19	W	20	W	20	W	20	W
Blackfoot Dam	4.9	5	SW	5	SW	4	SW	5	SW	5	SW	5	SW	5	SW	5	SW	5	SW	5	SW	5	SW	4	SW	5	SW
Border	16.9	17	W	17	W	17	W	17	W	18	W	17	W	17	W	18	W	16	W	16	W	17	W	16	W	17	W
Chesterfield	2.1	1	S	2	SW	3	W	2	W	3	W	3	W	2	W	2	W	2	W	2	W	2	W	1	S	2	W
Cokeville	9.4	10	W	10	W	10	W	9	W	10	W	10	W	9	W	9	W	10	W	9	W	8	NW	9	W	10	W
Fort Hall	4.3	5	SW	5	SW	5	SW	5	SW	4	SW	5	SW	3	SW	5	SW	3	SW	4	SW	3	SW	4	SW	5	SW
Grace	2.3	3	S	2	S	1	S	2	NW	1	W	3	S	3	W	3	W	2	S	3	SW	1	N	3	S	2	S
Grays Lake	1.6	3	SW	1	SW	3	SW	2	SW	..	....	3	SW	3	SW	1	SW	..	....	..	....	1	SW	2	SW	1	SW
Idaho Falls	7.1	8	NE	8	NE	8	NE	8	NE	8	NE	6	NE	7	NE	7	NE	7	NE	5	NE	6	NE	7	NE	6	NE
Montpelier	2.1	3	N	3	S	2	N	3	N	2	W	2	NW	2	S	2	N	2	NW	2	N	1	N	1	N	2	N
Paris	15.0	15	NW	15	NW	15	W	15	W	15	W	15	W	15	W	15	NW	15	NW	15	NW	15	W	15	W	15	W
Pocatello	14.0	14	SE	19	SE	14	SE	14	SE	14	SW	14	SE	14	SE	14	SE	14	SE	14	SE	14	SE	14	SE	14	SE
Thayne	7.0	7	SE	7	SE	7	SE	7	SE	7	SW	7	W	7	W	7	SW	7	W	7	W	7	SE	7	SE	7	SE
Region	7.2	8	W	8	SW	8	W	8	W	9	W	8	W	8	W	8	W	8	W	8	W	7	W	8	W	7.9	W

Table 9. Frost Data

Station	Length of Available Record: Years	Average Date of First Killing Frost in Autumn		Average Date of Last Killing Frost in Spring		Earliest Date of Killing Frost in Autumn		Latest Date of Killing Frost in Spring		Length of Growing Season: Average Number of Days Between Last and First Killing Frost	
		Yrs.	Date	Yrs.	Date	Yrs.	Date	Yrs.	Date	Yrs. Complete	Days
Afton	13	10	Aug. 23	10	June 14	13	Freezing temp. every month	12	Freezing temp. every month	8	61
Bedford	19	15	Aug. 25	15	June 27	19	Freezing temp. or lower every month	19	Freezing temp. or lower every month	18	60
Blackfoot Dam	4	4	Aug. 29	4	June 11	4	Aug. 14	4	June 23	4	78
Border	17	13	Aug. 27	13	June 22	17	Freezing temp. or lower every month	17	Freezing temp. or lower every month	14	61
Chesterfield	4	4	Aug. 15	4	June 25	4	July 1	4	June 30	4	50
Cokeville	9	5	Aug. 18	5	June 5	9	Freezing temp. every month	9	Freezing temp. every month	8	69
Fort Hall	4	4	Sep. 26	4	May 27	4	Sep. 10	4	June 13	4	122
Geneva	4	4	Sep. 4	4	July 6	4	Aug. 22	4	July 19	4	59
Grace	4	4	Sep. 23	3	May 29	4	Sep. 9	3	June 13	3	116
Grays Lake	2	..	.....	..	......	1	Sep. 14	2	June 30	1	93
Idaho Falls	8	4	Sep. 12	4	May 22	8	Aug. 31	8	June 20	8	122
Montpelier	3	3	Sep. 6	3	June 7	3	Aug. 22	3	June 30	3	90
Paris	13	13	Sep. 3	13	June 14	13	Aug. 9	13	June 28	13	80
Pocatello	13	9	Oct. 12	9	Apr. 20	13	Sep. 14	13	May 15	13	167
Pocatello Nursery	3	3	Sep. 26	3	June 19	3	Sep. 10	3	June 26	3	98
Thayne	6	6	Sep. 1	6	June 28	6	Aug. 18	6	July 9	6	63
Region	8 4	7	Sep. 4	7	June 10	8	Freezing temp. every month	8	Freezing temp. every month	7	86

for each station for each month and for the year. Table 8 shows the prevailing wind direction, and Table 9 gives frost data and shows the length of the growing season at each station and for the region.

In all these tables, where monthly records are given, a parallel column for each month shows the number of years for which the record of that month is available at the given station. From these parallel columns the average length of the available record in years, shown in another column, is computed. This column is used for computing the annual means, but another column is added to show the number of complete years for which the record at any station is available. In the regional summary included in most of the tables the averages are weighted according to the lengths of the records at the respective stations.

RAINFALL.—The climate of the region is semi-arid with an annual rainfall for the stations named ranging from 9.57 inches (Fort Hall) to 18.59 inches (Afton). The average for the region as determined by the given records is 14.27 inches. In the mountains the quantity is doubtless somewhat greater but no stations have thus far been maintained in the actual mountains. Table 2 shows the distribution of the precipitation throughout the year.

The maximum mean monthly rainfall for the region, as shown in Fig. 2, A, is 1.75 inches and occurs in May, but at Blackfoot Dam and Montpelier the maximum occurs in February; at Idaho Falls, Paris, and Pocatello it is in March; and at Border and Cokeville it is in April. At some stations, such as Blackfoot Dam and Montpelier, the length of the record is so short that the time of occurrence of the maximum may have been unduly affected by a few severe storms. At other stations, such as Idaho Falls and Pocatello, where the record is longer, it is probable that local conditions affect the time of occurrence of the maximum so that it is habitually earlier than that for the region. Lesser maxima occur in March (1.46 inches) and in October (1.23 inches).

The minimum rainfall for the year occurs in July and August, for each of which months the mean annual amount is .77 inches. This occurs chiefly during thunder showers. Secondary minima occur in November, with a mean of .88 inches, and in April, with a mean of 1.26 inches. Thus precipitation throughout the year is well distributed but is marked by fairly systematic fluctuations.

Thayne has the largest number of rainy days (113, see Table 3) but both Bedford and Afton have more precipitation, probably because they are situated nearer the windward base of high mountains. The lowest recorded number of rainy days for the year in the region is 66, at Geneva and at Blackfoot Dam. The records at both of these stations

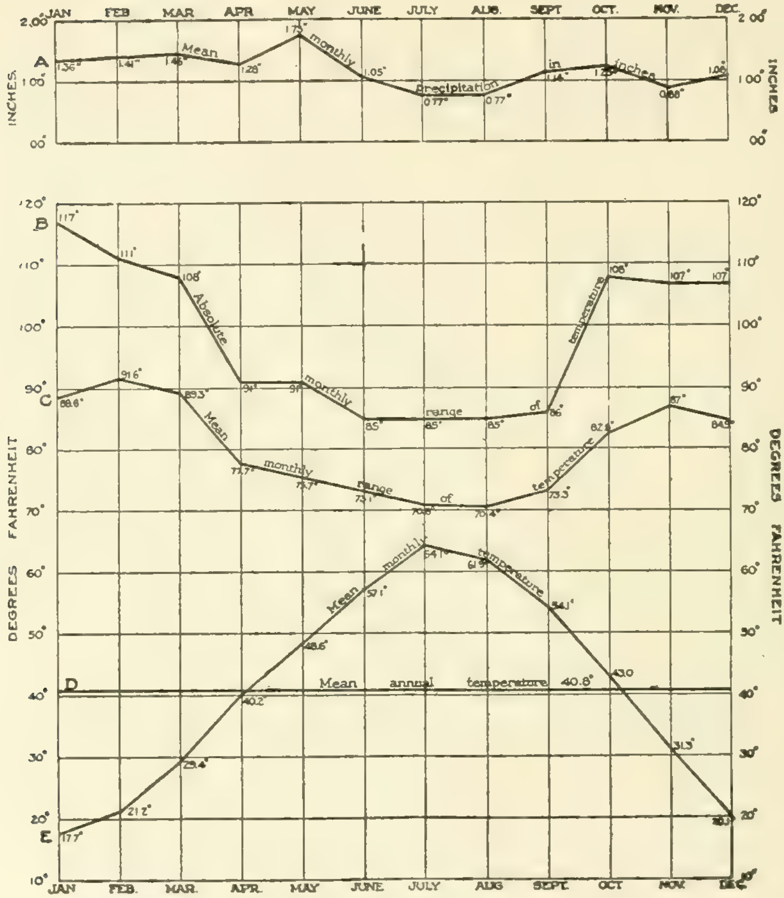

FIG. 2.—Graphic summary of precipitation and temperature data

are so short that they do not afford a satisfactory average. Probably observations for longer periods would show higher results, for the average for the region is 84 rainy days per year.

The snowfall for the region, Table 4, is fairly heavy, the mean annual amount being 70.8 inches or nearly 6 feet, unmelted. The maximum monthly average is 15.8 inches, which is the amount occurring both in January and in February. Snowfall is recorded at most of the stations in all months except July and August and at Border a trace of snow is even recorded in July. The heaviest annual snowfall is reported at Bedford, 99.6 inches, and at Afton, 82.0 inches. Both these stations lie at the windward base of the Salt River Range, which a few miles eastward reaches altitudes greater than 10,000 feet. The largest average amount recorded for any month at any station is 24.4 inches for February at Montpelier. The record for this station covers

so short a period that it has doubtless been unduly affected by severe storms. In the mountains the snowfall is without doubt heavier than at the stations which furnish the available records, a fact attested by the frequency of snowslides in the canyons, some of which have caused loss of life and property.

TEMPERATURES.—Southern Idaho lies outside the usual tracks of storms, so that both storms and cold waves are relatively infrequent and the temperature as a whole is equable. In southeastern Idaho, however. the valleys are higher than they are farther west and are bordered by fairly high mountains. Thus, extremes of temperature are somewhat more marked in that region. Local topographic conditions exert a marked control upon the climate in different parts of the district.

Table 5 shows the highest recorded temperatures of each station for each month and for the period, and also the mean of the highest temperatures and the absolute highest temperature for each month and for the period for the region. Table 6 gives similar data for the lowest temperatures. July has the hottest days at all but two of the stations, the absolute maximum or the actual highest recorded temperature being 103 degrees, indicated at two stations, namely, Grace and Grays Lake. The mean of the highest temperatures for the same month for the region is only a few degrees lower, 97.6. The lowest temperatures at a majority of the stations, including all but one of those with the longer records, are in February, the absolute minimum being 48 degrees below zero, recorded at Border. The mean of the minima for the same month is —36.3 degrees. The mean of the minima for the region is —40.4 degrees. Afton, Bedford, Cokeville, Grays Lake, and Thayne all have recorded minima lower than 40 degrees below zero.

The difference between the absolute maximum and the absolute minimum temperature for a given month is the absolute range of temperature for that month. Similarly the difference between the mean of the highest temperatures and the mean of the lowest temperatures for a given month is the mean range of temperature for that month. Figure 2, B and C, shows the absolute monthly and mean monthly ranges of temperature for the region. The absolute range is greatest in January, 117 degrees. It diminishes gradually to March (108°), more abruptly to April and May (each 91°) and again gradually to June, the minimum, (85°). The absolute range continues practically uniform from June through September but in October it increases rapidly to 108°, again remaining nearly uniform for the remainder of the year. The mean monthly range is also greater in the months from October to March, the two maxima being in February (91.6°) and in October (87°). From March (89.5°) to April (77.7°)

the decrease is rather abrupt as in the case of the absolute monthly mean. From April to July, however, the decrease is more gradual. For July and August the mean monthly range is nearly the same but the figure for August, which is also the minimum (70.4) is slightly lower. For September the mean monthly range is somewhat higher but there is a sharp increase in October, as in the case of the absolute monthly range.

A noteworthy feature is the mean of the lowest temperatures for the summer months. This bears witness to the coolness of the summer nights and shows the danger of frost incurred by crops growing on bottom lands, where cool air may stagnate.

The extreme temperatures noted above fortunately do not long persist for the mean temperature of the warmest month for the region is only 64.1° (July), see Table 7, and that for the coldest month is 17.7° (January). The stations recording the highest mean temperatures for the warmest and coldest months are respectively Pocatello 71.5° (July) and Border 12.8° (January). The mean annual temperature for the region is 40.8°. The mean monthly temperature curve for the region, see Fig. 2 D and E, is fairly uniform, rising gradually from January (17.7°) to February (21.2°) and then more rapidly at a nearly even rate to July (64.1°). The fall from July to August (61.9°) is rather gentle but from August to December (20.1°) it is more rapid and again nearly even.

It is probable that Bear Lake exerts a modifying influence upon the temperature of territory adjacent to it but the arrangement and records of the stations are not such as to make this influence clearly evident. The effects of difference in altitude upon the annual mean temperature are perhaps shown in a general way since the stations with the higher means have on the whole lower altitudes than those with lower means. This effect, however, is overshadowed to some extent by local conditions. Thus Grace, which is 900 feet higher than Fort Hall has nearly the same mean annual temperature. It is possible that Pocatello, which has the highest mean annual temperature of all the stations, 47.6°, may owe its excess of temperature in part to the warming, by compression, of the cool air that descends from neighboring uplands into the relatively narrow valley of Portneuf River.

Winds.—The prevailing winds, see Table 8, are westerly and ordinarily not of great velocity except on the more exposed slopes and at higher altitudes. Local conditions again play an important part in the control of wind direction. Thus stations like Fort Hall, which permit a practically unrestricted sweep for the wind, have westerly winds the year round. Other stations like Pocatello and Idaho Falls, situated in more or less restricted valleys have their wind direction

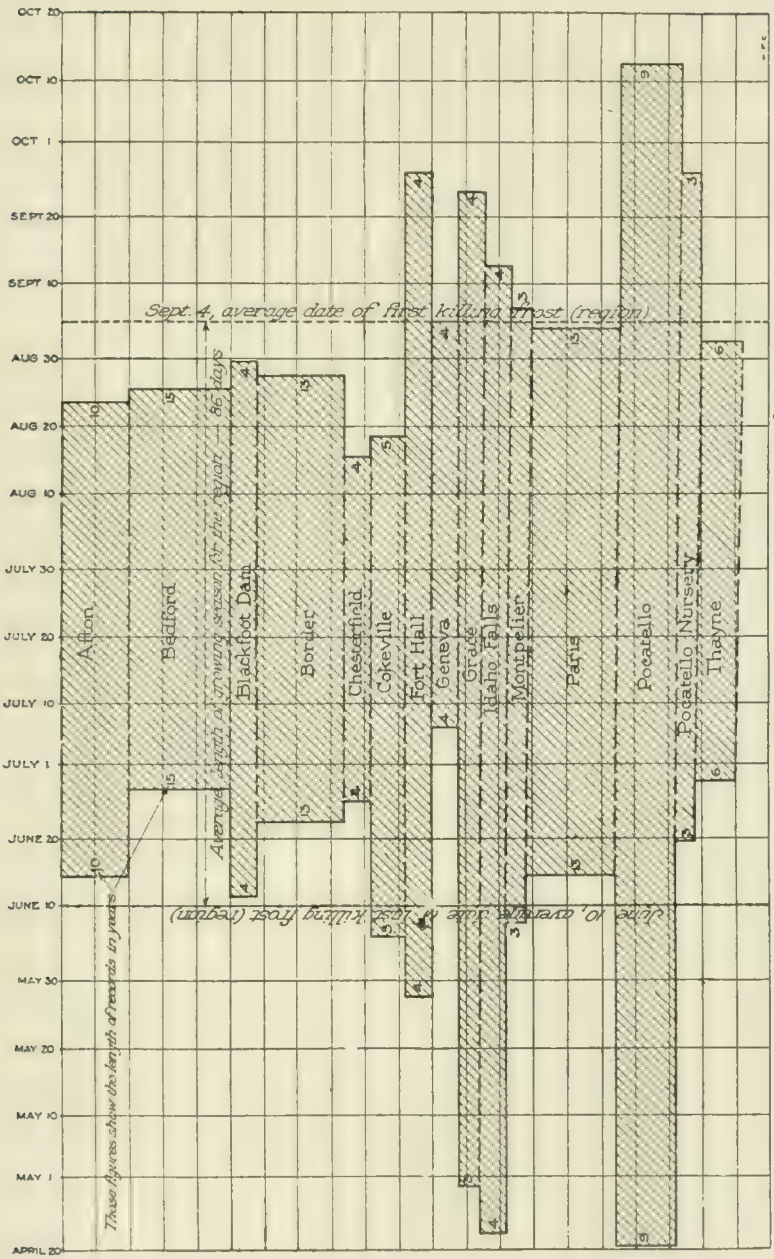

FIG. 4.—First and last killing frost and length of the growing season at fifteen stations in Southwestern Idaho and Western Wyoming

modified by these valleys. Thunder storms are of frequent occurrence in July and August but they often clear away over the broader valleys and yield little rain except in the higher hills. Convectional whirls bearing clouds of dust and light objects, such as bits of grass and sage brush, occur in some of the broader and drier valleys.

Frosts and the Growing Season.—In a general discussion of frost conditions throughout the United States Reed[3] presents a series of maps from which data bearing upon southeastern Idaho may be gathered.

The season of security from destructive frosts at the stations named, as compiled from the other reports previously cited, is shown in Table 9. At many stations, see also Table 6, freezing temperatures have been reported for every month in the year. In general, however, a growing season ranging in length from 50 days (Chesterfield) to 167 days (Pocatello) and averaging 86 days for the region may be expected. It is probable that the lowest figure is unduly small because of the brevity of the available record. The length of the growing season at a given station as compared with that at other stations is shown graphically in Fig. 3.

The stations with the longer growing seasons are in general lower than those where the season is shorter but, as in the distribution of mean temperature, local physiographic conditions play an important part. Pocatello Nursery, which is nearly 1,000 feet higher than Pocatello, has a much shorter growing season than that station. This difference is doubtless due in part to the greater altitude, but the former station may also lack other physiographic advantages enjoyed by the latter (see page 90). Comparison of Tables 9 and 7 shows the close correspondence of length of growing season and mean temperature at the respective stations. Thus Pocatello, Idaho Falls, Grace, and Fort Hall, which have the longer growing seasons, have also the higher mean temperatures. For much of the region a growing season of more than 60 days may reasonably be expected but the time may be extended if physiographic conditions warrant. Thus the bottom lands, as previously noted, are subject to frost and are therefore not adapted to any but the hardiest crops. They are largely given over to the production of wild hay. On the other hand along the sides of the valleys, on slightly higher ground, the cold air does not linger, and valuable crops, such as wheat, oats, rye, alfalfa, hay, and potatoes, may be raised. In the larger valleys considerable areas are suitable for irrigation but the practice of dry farming is increasing and all the larger soil areas whether irrigable or not, are being rapidly taken up for cultivation.

[3] Reed, W. G., Frost and the growing season; U. S. Dept. Agr., Office of Farm Management, Atlas of American Agriculture, Part 2, Climate, 1918, Washington.

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MEMOIR OF ROBERT EDWIN PEARY

WILLIAM HERBERT HOBBS

The attainment of the earth's northern geographic pole, for nearly four centuries the great goal of exploration, was an achievement surpassing all others in general interest and one which aroused the patriotic pride of the American people in no small degree. That the sturdy American who succeeded after devoting a life-time to the attainment of this goal should, through no fault of his own, have been defrauded of his immediate reward in the acclaim of his country and made the object of vicious attack through the greatest scientific hoax which history records, is one of the outstanding tragedies of polar exploration.

Throughout Europe with the exception of Denmark, the strident claims of the imposter produced little reaction, but with a license which is nothing if not American the already discredited claimant for polar honors in the rôle of a vaudeville performer sought to signalize every appearance of Peary for a public address by his own presence in the same vicinity where, from the local stage and often through the local press, he launched his torrent of abuse with such vigor as to supply all needed advertisement for his own further appearances. Only when the great explorer was stricken down by the illness which led up to his death did this profitable career of infamy come to an end,—whereupon this experienced fakir deserted the stage for other now more profitable fields.

If the attainment of the northern pole bulks largest in the popular mind among the achievements of Admiral Peary, in the estimation of geographers it hardly surpasses those other discoveries mainly upon the Greenland continent which will always be connected with his name. It was his merit to have introduced into the exploration of the polar regions new and improved methods of attack which have transformed both the strategy and the tactics of polar campaigns. It was the "Peary System" of supporting parties which eventually conquered both the northern and the southern pole, though the methods were different in the two regions. It was his discovery of the advantages of the "Imperial Highway" across the inland-ice which, followed not only by Peary himself, but by Nansen, de Quervain, Koch and Wegener, and by Rasmussen, has made known to the world the vast interior of the Greenland continent.

Before Peary's methods were adopted it was apparently the rather general opinion of Arctic explorers that journeys in the winter season were impracticable by reason of the extreme cold, and Sir George Nares is quoted as saying that any officer should be censured if he exposed

his men to the hardships of winter travel. Peary conquered the cold by the adoption of suitable fur clothing, and he carried out his successful polar campaign in the latter part of the winter season, arriving at the Pole on the 6th of April. It is, in fact, doubtful if it could have been reached over the ice in the summer season.

It was Peary's great discovery also that above the inland-ice all strong surface air currents blow down the slope. This observation made it obvious that continental glaciers have an auto-circulation and make their own weather, instead of having it brought to them by the migrating whirls of the atmosphere.

It is perhaps well to point out that the hazard involved in exploration within the North Polar region is very much greater than that in the region surrounding the opposite pole. The former is a frozen sea traversed by a network of hummocky ice ridges and of lanes of open water. Both these networks shift their position and change their pattern without warning, at the caprice of the winds. As well might one expect to recover a depot of supplies set adrift upon a raft in the open sea, as to recover anything which has been cached upon the ice of the Arctic Sea. On the contrary, the surface of the South Polar region is almost as stable as *terra firma,* and the explorer is assured that his back trail will remain where he left it.

The more important events of Peary's life may be set down in order. Born in Cresson, Pennsylvania, on May 6, 1856, he studied at Bowdoin College, where he distinguished himself both in scholarship and in athletics, and where he received its degree of Civil Engineer in 1877. After a term of service as draftsman in the U. S. Coast and Geodetic Survey, he entered the United States Navy as civil engineer in 1881, and in 1884-85 was assistant engineer on the surveys for a Nicaraguan Ship Canal, and engineer-in-charge in the period from 1887 to 1888.

Peary's polar work had, however, been started in 1886 when he carried out a reconnaissance upon the inland-ice of Greenland to the eastward of Disco Bay. This trip was undertaken with one companion, the Danish officer, Maigaard, and Peary succeeded in ascending one of the outlets of the inland-ice and in going due eastward until he had reached a point nearly one hundred miles from the margin and at an elevation of 7,500 feet. He supplied a better picture of the essential conditions and seasonal variations within the marginal area of the inland-ice than had before been set forth, and his reconnaissance was of prime importance in proving to him the entire feasibility of travel across the continent, once the height of the plateau has been reached. This journey thus paved the way for the epoch-making sledge journeys which he carried out later in northern Greenland. Writing in 1887 of a small party equipped according to his then method, he declared confidently, "the deep, dry, unchanging snow of the interior is not a *bête*

noir, but something to be reached, as noted above, at the earliest possible moment, and once reached, it is an imperial highway, over which a direct course can be taken to the east coast." He appears at this time not to have known that Baron Nordenskiöld had already in 1870 and again a few years before, carried out a somewhat similar journey from near the same base, for he wrote in 1898, "For the first time the deep, unchanging, incoherent snow of the central plateau was reached. . . ."

The North Greenland Expedition of 1891-92 was undertaken to test out the methods learned from the reconnaissance of 1886, and despite the fact that shortly after reaching Greenland with this expedition Peary had been struck by the iron tiller of his ship and had both bones of his right leg broken above the ankle, he none the less succeeded in carrying out the purpose of his expedition and established a record for long distance dog sledging without a cache from beginning to end in a thirteen hundred mile journey. On this expedition he discovered an arm of the East Greenland Sea to the eastward of the Greenland continent and christened it Independence Bay. The success achieved in this expedition was in no small measure to be ascribed to the adoption of suitable clothing. Of this fur clothing of Eskimo pattern, he declared: "I could keep perfectly warm and yet not get into a perspiration in temperatures from +40° F. to —50° F. whether at rest, or walking, or pulling upon a sledge." No tent was carried and no sleeping bags, the fur clothing affording ample protection both day and night.

This expedition for the first time made probable, though it did not prove, the insularity of Greenland; it showed the nature of the surface of the inland-ice throughout a wide zone, the outward circulation of air above its surface, and the rough delimitation of almost the entire northwest coast of Greenland. In addition detailed maps were prepared of Inglefield Gulf and of Whale and Murchison Sounds.

Peary's statement concerning the outward air circulation above the inland-ice, as made to the Royal Geographical Society, may well be cited here, since it represents the first clear exposition of a fact now well established:

"There is one thing of special interest to the glacialist—the transportation of snow on the ice-cap by the wind. No one who has not been there can have any conception of its magnitude. The wind is always blowing, and blowing always on lines which would be gravity lines from the interior. The regularity of the winds of the 'Great Ice' of Greeland, as I have found them during an actual sojourn of over seven months upon the ice-cap and visits to it of greater or less duration in every month of the year, is phenomenal. Except during atmospheric disturbances of exceptional magnitude, which cause storms to sweep across the country against all ordinary rules, the direction of the wind

of the 'Great Ice' of Greenland, is invariably radial from the center outward, normal to the nearest part of the coast-land ribbon. So steady is this wind, and so closely does it adhere to this normal course, that I can liken it only to the flow of a sheet of water descending the slopes from the central interior to the coast."

No sooner had Peary returned from the expedition of 1891-92 than he set himself to work to secure the funds and the necessary outfit for a second expedition to the same region. As a consequence he found no time to set forth the scientific results of the last one and Dr. Cyrus C. Adams, then of the American Geographical Society, making use of Peary's material, with his permission, presented a very valuable summary in the *Geographical Journal.*

The expedition of 1893-95 was carried out under the auspices of the Geographical Club of Philadelphia, later to become the Geographical Society of Philadelphia. This expedition resulted in a new transection of northern Greenland and the discovery of the three Cape York meteoric irons, one of them the largest known to exist.

A disaster which would have disheartened almost any explorer befell the expedition. A depot which had been established upon the inland-ice in preparation for the long journey and which contained almost the entire supply of provisions (nearly a ton and a half), was buried and lost beneath the drift-snow of a terrific blizzard which continued throughout six days and nights. After diligent but futile search for the buried cache, Peary felt himself in the position of a man shipwrecked, and he wrote,

> "What should I, what could I do? and yet the idea of abandoning the journey never for a moment occurred to me, nor I think to either of my companions. It would be necessary to revert to first principles, revise our programme, and then trust to the Almighty. . . . As it was, my favorite nightmare during the winter was to dream that I was back home again without having been able to make another attack upon the ice-cap and I would waken with a feeling of positive relief to find myself stretched on my bearskin with the howling wind of the great night tearing at the house, and to realize that I still had the struggle before me. That I had reason for this fear will be understood from our utter lack of any margin for accidents or mishaps, either to ourselves, our material, or our supplies."

Peary's companions, Lee and Henson, were indeed for a considerable period incapacitated, the former because of exhaustion after an arduous surveying trip, and the latter from the grippe. Peary himself in lashing down a sledge in the midst of a storm was nearly brained by a heavy box of frozen meat which was blown from the roof of the hut and which, grazing his temple, rendered him arm useless for a week. Again, on a trip to Cape York in the midst of the Arctic night Peary narrowly escaped being engulfed with his team when a big berg capsized and smashed the ice about him.

In the first attempt to cross the inland-ice during the season of 1894, Peary's party encountered a blizzard at that time unprecedented for severity in the annals of Arctic work and several of his dogs were frozen as they slept, though the members of the party in their fur clothing suffered only frozen fingers and toes. For thirty-four hours the average air temperature was —50° F. and the wind velocity nearly fifty miles per hour. Pushing on in the continuous cold, the remaining dogs developed dog madness and the party was compelled to return. After wintering at the base Peary again set out in April, 1895, and this time reached Independence Bay. Profiting by the experiences gained during his first trip across the inland-ice in 1891-92, the course was this time laid between the former outgoing and returning courses, with the object of avoiding the basins of exudation with their heavy slopes and crevassed ice, and also the deep soft snow which made difficult sledging in the interior areas. For this journey Peary by reason of the disaster which had befallen him in the loss of his supplies, was absolutely dependent upon a supply of meat from musk oxen which he expected to secure near Independence Bay, where he planned to recuperate before setting out upon the return. In this plan he was successful and the return was made without encountering any delay from blizzards, a most unfortunate circumstance, since all his provisions and one of the dogs were consumed upon the journey. During this Arctic expedition he carried out a thorough ethnological study of the little tribe of Eskimo highlanders on Inglefield Gulf.

Returning to the United States from this expedition he brought back with him the two smaller meteoric irons which he had discovered at Cape York. The largest mass, weighing about ninety tons, he was able to bring away only after he had made two special summer expeditions for the purpose. The first of these made in 1896 succeeded insofar only as to get the mass out of its bed and transported to the shore. At this juncture the pack began to drive and forced a sudden departure of his ship in order to escape being crushed. In 1897 a second expedition under his direction was successful in embarking the great meteorite and transporting it to New York City where it now rests.

Referring to the work accomplished by Peary up to this time, Sir Clements Markham, the veteran British Arctic explorer and the President of the Royal Geographical Society, said, "Lieutenant Peary is, without exception, the greatest glacial traveller in the world. He is also far and away the greatest dog-sledge traveller in the world as regards rapidity and distance."

In 1898 Peary set out upon his sixth Arctic expedition which was destined to extend over a period of more than four years and which, although it failed of its main object—the attainment of the Pole—will always rank among the most important of all Arctic journeys for what

was accomplished, and as a record of courage and fortitude in the face of heart-breaking discouragements it is unsurpassed.

In December, 1898, because of thick weather and heavy snows which held up the party on an expedition from Etah to Fort Conger, the supplies ran out. Pushing ahead with the strongest of the Eskimo, Peary reached Fort Conger after living on the dogs and going without sleep only to find that both his feet were so seriously frozen, that he had to lie upon his back throughout the winter. Lashed to a sledge he was dragged a distance of 250 miles in daily temperatures below —50° F. Arriving at the base eight of his toes had to be amputated; yet only a month later with the wounds still but partly healed he accomplished a second sledge trip to Fort Conger, and in this condition also he effected a crossing of the ice-cap of Ellesmere Land, which he had already shown to be continuous with Grinnell Land.

Before he could walk without distress it was necessary to break in a new set of tendons and muscles for both of his feet, and disagreeable though the process was, it was at last accomplished and the scars healed.

On the 9th of April, 1899, Peary started northeastward in an effort to reach the northeast corner of Greenland by way of the coast, and after meeting and overcoming the greatest difficulties he accomplished his purpose. Doubling the cape, to which he gave the name Cape Morris K. Jesup, he proceeded southward along the east coast of Greenland until he had sighted the high mountain (Mt. Wistar) which he had described some years before, when looking out from the height of the inland-ice west of Independence Bay. Thus, though he had not completely closed his two traverses, he conclusively proved the insularity of Greenland, and nine years later Capt. J. P. Koch of the Danish Northeast Greenland Expedition, advancing northward from Cape Bismark, mapped the intervening gap, and reaching Peary's cairn brought back to civilization the record which Peary had deposited there.

After the return from northeast Greenland to his base and still in the midst of winter, Peary on February 11th launched an attempt to reach the Pole, though this involved travelling four hundred miles in addition to what had lain before the earlier British expeditions in their attempts. On the trip to Fort Conger he covered the three hundred miles from Payer Harbor to the fort in twelve marches. With temperatures ranging from —40° F. to —67° F., four days were spent at the fort in fruitless attempts to secure musk oxen. On February 24th Peary started northward with nine sledges and on April 6th, after being in the field a month and covering four hundred miles of the most arduous travelling imaginable, he left the land at Crozier Island and struck northward across the pack in the direction of the Pole. After fifteen days of heart-breaking labor with dogs now about used up, he turned back on April 21st after attaining lat. 84° 17′ N., the highest

then reached in the Western Hemisphere. He entered in his diary: "The game is off. My dream of sixteen years is ended. . . . I have made the best fight I knew. I believe it has been a good one; but I cannot accomplish the impossible."

When in an address before the Royal Geographical Society, Peary had finished his narrative of this expedition, Admiral Sir Lewis Beaumont, himself a veteran Arctic explorer, declared: "I am glad to say that there is no jealousy among Arctic explorers, and if there is anyone here tonight who is ready to give him the meed of praise he deserves, it must be those who have had the privilege of being in those regions themselves. I think you will agree that to be four years in the Arctic Region is in itself a wonderful test of manhood and endurance, and to have accomplished in addition to those four years the extraordinary and wonderful journeys which we have just been told of, makes a record in Arctic history which stands almost unsurpassed. . . . I want you to appreciate how great was the work done by Commander Peary; that, starting from half way down Smith Sound 400 miles from the starting point of the three other expeditions, he has accomplished more than they. I consider it due first to the man himself who has shown himself every inch a man. . . ."

Undismayed by repeated disappointments in earlier expeditions, and notwithstanding the fact that he had now passed the age when men are considered fit to endure the continued hardships of polar work, Peary organized his seventh expedition to conquer the Pole. All the experience of his earlier expeditions was fully utilized, and this time a special type of ship, the "Roosevelt," was designed by Peary and built with a view to withstanding ice pressures and take the expedition through the dangerous Kennedy and Robeson channels to a base on the northern coast of Grant Land, from which the start could be begun at once upon the pack of the central polar sea.

A system of supporting parties described below under his last expedition was now for the first time devised and put into use in polar work. The expedition sailed north in July, 1905, and returned in October, 1906, after reaching the extreme northern latitude of 87° 6′, the farthest north by 38 statute miles that had ever been attained.

After leaving the shore of Grant Land and entering the pack, the party encountered much open water and was repeatedly held up by extensive leads, so that progress was very slow. Near latitude 85° a furious gale was encountered which continued for six days and drifted the party seventy miles to the eastward, so that it now became obvious that a dash from this point offered the only hope of attaining the Pole. On this dash, Peary reported, "as dogs gave out, unable to keep the pace, they were fed to the others. On April 20th we came into a region of open leads leading nearly north and south, and the ice motion

became more pronounced. Hurrying on between these a forced march was made. Then we slept a few hours, and, starting out again, soon after midnight, pushed on till noon of the 21st. My observations then gave 87° 6′.

"I thanked God with as good a grace as possible for what I had been able to accomplish, though it was but an empty bauble compared with the splendid jewel for which I was straining my life. But, looking at my remaining dogs and the nearly empty sledges, and bearing in mind the moving ice and the unknown quantity of the big lead between us and the nearest land, I felt that I had cut the margin as narrow as could be reasonably expected."

The return to the land proved to be full of peril, and it was reached on the shore of Greenland with food entirely exhausted. Here Peary was fortunate in finding a herd of musk oxen and in killing all seven of them, so that the party secured a meat supply sufficient to reach the base at Cape Sheridan. No man had been lost and 41 of the 120 dogs returned. Before returning to the United States Peary undertook a long sledge journey westward from Cape Sheridan and then completed the exploration of the entire northwest coast of Grant Land to Cape Thomas Hubbard. It was from the top of this promontory that he observed far to the westward what seemed to be a land sky upon the basis of which he gave out the probability of a new land mass which he called Crocker Land. The later expedition by Macmillan indicated that this does not exist, though from the height of the promontory Macmillan received the same impression that Peary did.

In July, 1908, Peary started on his eighth and last expedition in which he finally perfected the plan of supporting expeditions for journeys across the Arctic pack. On this expedition he established his base at Cape Sheridan and entered the pack near the same point as before. This time he reaped the harvest from years of determined effort and achieved the Pole. With twenty Eskimo men, seventeen women, ten children, 246 dogs, and a large supply of walrus meat, the "Roosevelt" reached its winter quarters through the heavy ice runs in Robeson Channel, and a depot of supplies was at once laid down at Cape Columbia, the northernmost point of the Arctic archipelago. The early part of the following winter was devoted to hardening his men by undertaking frequent winter sledging trips, with the result that when the expedition started in the late winter every man and dog was "lean and flat-bellied as a board and as hard." Peary's plan to achieve his purpose consisted in organizing four supportng parties to the main party which alone was to attempt to reach the Pole. For the first lap of the journey supplies for the entire expedition were to be taken from one sledge until only enough was left upon it for its return, whereupon with the least fit of the dogs and men it should return to the base.

The same process was applied in the case of the other supporting sledge parties in succession until Peary with the very fittest of men and dogs and with ample supplies upon the main sledge should make his dash for the Pole. The results proved the wisdom of the plan, which worked out almost to perfection, notwithstanding the fact that the party was held up for six days at the "big lead" which forms over the edge of the continental shelf. By having one party sleep while the next succeeding one was travelling, one set of snow huts were used for both and much time saved, the advanced party turning out of the *igloos* when the following one arrived.

When in latitude 87° 48′ at a point distant 130 miles from the Pole, Captain Bartlett who commanded the last supporting party, turned back and Peary wrote, "With the disappearance of Bartlett I turned to the problem before me. This was what I had worked for during twenty-three years; for which I had lived the simple life; for which I had conserved all my energy on the upward trip; for which I had trained myself as for a race. . . . Underlying all these calculations was a recognition of the ever present possibility of open leads, and impassable water, and the knowledge that a twenty-four hours' gale would knock all my plans into a cocked hat, and even put us in imminent peril." When at last with Henson and four Eskimos Peary had accomplished his dash in five marches and reached the Pole on April 6, 1909, he wrote in his diary:

"The Pole at last! The prize of three centuries, my dream and goal for twenty years, mine at last! I cannot bring myself to realize it.

"It all seems so simple and commonplace. As Bartlett said when turning back, when speaking of his being in these exclusive regions, which no mortal had ever penetrated before:

"'It is just like every day!'"

When he had spent thirty hours in making observations at the Pole and had undertaken a deep sounding at a point five miles distant and found no bottom at 1,500 fathoms, the back trail was taken and Cape Columbia reached in sixteen forced marches. Once safely across the "big lead" and upon the land-ice of the glacial fringe without the much feared gale having intervened, the Eskimos of the party went wild with delight and relief, danced and sang, and Otah exclaimed feelingly, "The devil is asleep or having trouble with his wife, or we never should have got back so easily." Such wind as was encountered on the journey had fortunately been from the north, thus keeping the ice pressed against the land and the leads generally closed. The weather, which had so often before dashed Peary's hopes, now for once had greatly favored him.

The scientific results of the expedition, in addition to proving the central polar sea, included a number of soundings which showed that

the continental shelf, unlike that in moderate latitudes, was characterized by landward as well as seaward slopes, a fact proven also for the eastern slope of Greenland by the observations of the Danish Northeast Greenland Expedition concluded the year before.

No sooner had Peary returned to the frontiers of civilization than he learned with astonishment that Dr. Frederick A. Cook had shortly before put forth the claim to have reached the North Pole nearly a year in advance of himself. No account of Peary's life could fail to take account of an event which bulks so large as the so-called "Cook-Peary Controversy," and, painful as it will always be for American geographers to recall it, the smouldering embers of popular distrust and misinformation demand imperatively that at least the salient facts in the greatest of scientific fakes should be here reviewed.

Dr. Frederick A. Cook at the time of Peary's conquest of the Pole had been a member of several polar expeditions, notably that of the "Belgica" expedition to the Antarctic in 1897-99 and of Peary's expedition to North Greenland in 1891-92. He had also between 1903 and 1906 directed several expeditions in attempts to ascend Mt. McKinley in Alaska and had made the claim to have ascended the mountain in 1906 in company with one guide, after the main expedition had been disbanded. His alleged photograph presenting the summit at 21,000 feet of altitude showed soft snow, in appearance quite unlike the hard-packed snow of the summits of high peaks.

At some time previous to Peary's return from his successful polar expedition (August, 1907, according to Cook), Cook had been landed from a private yacht on the shores of Smith Sound, and in the company of Eskimos had made an excursion westward across Ellesmere Land. This much seems to be well established by the testimony of his companions and through his examination by Captain Sverdrup at Copenhagen. According to his claims he accomplished the thirteen hundred miles to the Pole and return, whereas the Eskimos who were his companions testified that he went "two sleeps" only on the ice before returning. When Captain Bartlett returned to the base with the report that he had left Peary 130 miles only from the Pole, Cook hurried back to civilization with the announcement that in April, 1908, or nearly a year before the date of Peary's arrival at the Pole, he had himself reached it. Peary, as soon as he got in touch with outside communications, declared the claims of Cook to be unfounded upon the basis of the testimony of the Eskimos who had been Cook's companions. Should Cook's claims be established, the reward would be almost entirely his, because of his alleged priority in attaining the Pole. None the less, Cook's clever retort that there was "glory enough for all" made a strong appeal to the American sense of fair play, since the American public was wholly unable to form a competent judgment

of the merits of the controversy. The followers of Cook in the contest which soon developed were especially numerous among the so-called "intellectuals," and no less than four well-known polar explorers gave their full endorsement to Cook during the early stages of the controversy. These were General Adolphus W. Greely, who had commanded an American polar expedition; Captain Ronald Amundsen, the distinguished Norwegian explorer; the well-known Danish explorer, Knud Rasmussen; and Captain E. B. Baldwin, who had commanded the Baldwin-Ziegler expedition to the Arctic in 1901.

Cook, instead of returning from the Arctic directly to the United States, took ship to Copenhagen, where Rasmussen's endorsement secured for him a great ovation. He was received in state by the crown prince of Denmark, the keys of the city were delivered to him, and the famous University of Copenhagen conferred upon him her Doctor of Laws. In the presence of vast throngs of the populace wreaths of laurel were hung about his neck. When the rector of the University requested that he be allowed to inspect the records made at the Pole, he was informed by Cook that these precious documents had been left in Northern Greenland in the keeping of a hunter of musk-oxen who was instructed to deliver them to Peary to be by him brought back to the United States on the "Roosevelt." Peary, knowing well that when they were found to be spurious he would be charged with having tampered with them, wisely refused to fall into the trap which was thus laid for him, for which he was denounced to the public as ungenerous to his rival.

Acclaimed at Copenhagen, Cook's arrival in the United States and his appearance before large audiences throughout the country, afforded him ovation after ovation and netted him great financial returns.

Anxious to end as soon as possible a disgraceful situation, though Peary with dignity had refused to take any further part in the controversy, the National Geographic Society appointed a committee of distinction and of much technical expertness to examine the records of Commander Peary. This committee consisted of Mr. Henry Gannett, chief geographer of the United States Geological Survey; Admiral Colby M. Chester of the United States Navy, and Superintendent O. H. Tittmann, the head of the United States Coast and Geodetic Survey. When invited to submit his records, Cook refused upon the ground that he had already promised to submit them first to Copenhagen. By cable the society then requested the University of Copenhagen to waive its rights under this promise so that the disagreeable controversy might be brought to an end, but its rector declined to accede. So the great lecture tour of Dr. Cook went on and the newspapers of the country continued to advertise the fraud in front-page articles.

When the evil day could no longer be put off, Cook submitted his

papers to the tribunal of his own choice at Copenhagen with the result that they were found to supply no proofs whatever, as was thereupon officially announced by the University. Rasmussen, whose endorsement had been largely responsible for the humiliating position in which this famous University now found itself, declared in an interview: "When I saw the observations, I realized that it was a scandal. The documents which Dr. Cook sent to the University are most impudent. It is the most childish sort of attempt at cheating."

Perhaps the most convincing proof of the gigantic fraud which had been perpetrated by Dr. Cook upon a susceptible public has been supplied by the discoveries of the explorer Stefansson, who, subsequent to the settlement of the controversy, discovered and explored a body of land lying directly athwart the path alleged by Cook to be the one he followed; and a point which Cook claimed to have located with especial accuracy and to represent the frozen surface of the sea, Stefansson found to be situated well inland from the coast of this newly discovered land and at an elevation of 800 feet above the sea.

As regards the alleged ascent by Cook of Mt. McKinley, Professor Herschel C. Parker of Columbia University, who had been a member of the earlier Cook expeditions, later led an independent expedition to the district and prepared photographs which show that the peak represented by Cook's published photographs to be the summit of Mt. McKinley is distant from it about twenty miles and has an elevation of about 8,000 feet, instead of 21,000. The late Arch-Deacon Stuck, who subsequently made the first ascent of Mt. McKinley, wrote in his narrative, "any one who climbs to the top will not need Edward Barrille's affidavit to convince him that Cook's narrative is untrue."

As a consequence of these exposures of fraud, the Alpine and Explorers' Clubs, the Arctic Club of America, and the Council of the Brooklyn Institute of Arts and Sciences, all by formal action, formally expelled Cook from their membership. Notwithstanding the exposures, Cook through his agents in Congress tried repeatedly to have action taken to declare him the discoverer of the North Pole, but succeeded only insofar as to have speeches denouncing Peary entered upon the congressional records.

The narrative of his journey and the observations made in the vicinity of the Pole were by Peary submitted to the expert boards selected by the National Geographic Society of Washington and to those of the Royal Geographical Society of London, as well as to a special committee of experts chosen by a congressional committee of investigation. All these boards alike reported that the evidence submitted fully substantiated all the claims of the explorer. The President of the Royal Geographical Society, when introducing Peary to the Society for an address upon the results of his expedition and for

the award of a second special gold medal, said: "I stand here tonight as the representative of the Royal Geographical Society, and armed with the full authority of the Council, to welcome you, Commander Peary, as the first and only human being who has ever led a party of his fellow creatures to a pole of the earth."

Admiral Sir Lewis Beaumont, in seconding the vote of thanks of the Society to Commander Peary, said:

"Commander Peary began by showing that he had in him all the personal qualities which enable a man to make great sledge journeys to the polar regions—in his fifteen years' work since he has shown that he also possesses the much higher qualities of rapid organization and good generalship.

"Under his leadership the zeal and enthusiasm of beginners have been made to accomplish the work of veterans—all the energy that has come within the sphere of his influence has been made to converge upon one subject; and while he has remained the brain, guide and commander, the work done by his assistants has been full of independent initiative and intelligence."

Captain Robert F. Scott, soon to forfeit his life to the hardships and perils of polar exploration just after achieving the opposite pole of the earth, said on the same occasion:

"I esteem it a great privilege to have been asked to support this motion (a vote of thanks of the Society to Commander Peary). It has been most fittingly proposed and seconded by three British explorers who have gained their laurels in the regions in which Commander Peary has achieved his great triumph. It is well that those who are most competent to judge should record their enthusiastic admiration of the unquenchable spirit with which Commander Peary has pursued his object, and their appreciation of the justice of the reward which has at length crowned his efforts."

Peary himself in evaluating his achievement said:

"Many factors have entered into the success of the expedition, but standing preeminently was *experience*. . . . In a previous expedition for the first time a true knowledge of actual conditions existing in the Central Polar basin had been secured; and with this combination it was possible to provide for practically every contingency. Added to this was the fortunate factor of a not unusual depth of snow on the icefields to impede us and the non-occurrence of strong easterly or westerly winds while we were on the ice. The occurrence of such winds, resulting as they would, in pronounced lateral motion of the ice, would have given us serious trouble."

Looking back over the expeditions as a whole, it is manifest that each led to new knowledge vital to success, which was fully made use of by Peary in all the later onsets of his campaigns. Throughout a

lifetime he had pitted himself against the cruel forces of Nature in these inhospitable regions, and out of repeated defeats he had at last achieved victory. For this, notwithstanding his mutilated members, his magnificent physique was a prime requisite, and though impaired by advancing years when the last battle was fought, he yet made it adequate for the task by simple habits and a spartan self-discipline.

Among geographers the recognition of his work followed upon his achievement of the Pole, though he had already been the recipient of many honors and of special gold medals in addition to those commonly awarded by the geographical societies. Now every important geographical society in the world in some way gave indication of its recognition of Peary's service to science. Special gold medals were awarded him by the National Geographic Society (Washington), The Royal Geographical Society (London), Philadelphia Geographical Society, Peary Arctic Club, and The Explorers Club (New York). The National Geographic Society awarded him in addition the Hubbard Medal, the Chicago Geographical Society the Culver Medal, the Philadelphia Geographical Society the Kane Gold Medal, the American Geographical Society (New York) the Daly and Cullom Gold Medals, and gold medals were awarded him by the Imperial German, Austrian, Hungarian, Royal Scottish, Italian, and Belgian geographical societies, not to mention many smaller organizations. Other honors came to him in the election as President of the American Geographical Society (1903), President of the 8th International Geographical Congress held at Washington in 1904, Honorary Vice-President of the 9th International Geographical Congress held at Geneva in 1908, and also the 10th held at Rome in 1913. He was elected President of the Explorers Club and later served as delegate of the United States government to the International Polar Commission which met in Rome in 1913. France recognized Peary's great triumph by making him a Grand Officer of the Legion of Honor.

When the special congressional investigating committee of experts which had been appointed to examine Peary's observations at the Pole had reported favorably, by special act a vote of thanks was extended to Peary by the Congress, and he was promoted to the rank and pay of Rear Admiral in the United States Navy.

Yet all these honors, great as they were and coming from those most competent to judge of the merits of his work, never fully compensated for the campaign of vindictive defamation which had been set on foot by Dr. Cook and which, kept up unceasingly almost until his death, estranged a large section of the American public and prevented a general recognition of his patriotic service just where he most yearned to have it. For the benefit of his countrymen the writer of this sketch feels constrained to describe the remarkable ovation which was ten-

dered Peary at the 10th International Geographical Congress held in Rome in the spring of 1913. This Congress was attended by an especially distinguished body of polar explorers, among them Stefansson, Cagni, and Bruce. It having early been rumored that Peary was to be in attendance, the writer found himself besieged by anxious inquirers to know whether it was really true. When Peary arrived it almost seemed as though other activities were forgotten, so great was the interest in seeing or meeting the great explorer. Dinners in Peary's honor were tendered in such rapid succession by the delegates from the different nations represented as to constitute a distinct strain upon him, from which he at last found relief in an excursion with the writer into the Roman Campagna.

The motive power which lay behind Peary's repeated determined attacks upon the Pole was a deep patriotic sentiment quite as much as it was his desire for personal success. Speaking before the Royal Geographical Society after his great disappointment of 1902, he declared, "The attainment of the Pole is peculiarly an object for American pride and patriotism. The North American world segment is our home, our natural ultimate destiny."

With the outbreak of the great war in Europe Peary threw himself into the campaign for preparedness, for with clear vision he saw in it the only sure way of meeting the peril which hung over his country and civilization itself. He spoke with great earnestness to many large audiences, and was often called upon by the Navy League and by other defense organizations to speak at their preparedness conventions. At other times he addressed large audiences from the same platform with General Wood.

The Aero Club of America appointed him one of its governors, and he became the principal protagonist for a coast patrol by seaplanes to guard the Atlantic seaboard against surprise, a system which was eventually put into force and taken over by the federal government.

In 1918 Peary was stricken with pernicious anemia and after thirty-five transfusions of blood had been made in succession to prolong his life, he passed away at his home in Washington on February 20, 1920, at the age of sixty-four years. At his bedside were the members of his immediate family: Mrs. Josephine Diebitsch Peary, who had more than once been his companion on Arctic expeditions; his daughter, Mrs. Edward Stafford, the "snow baby" who had been born in the Arctic; and his son, Robert Peary. He was buried in Arlington National Cemetery with full naval honors.

Thus passed from earth all that was mortal of the man whom Stefansson described as "easily the greatest of all explorers, North or South," and one who was loved for his sterling personal qualities by all who were privileged to know him intimately. His qualities of

leadership have been referred to by Captain R. A. Bartlett, the commander of the "Roosevelt" and one who knew him as did few others: "The Admiral was a born leader. . . . In every emergency during his trips he always thought of the welfare of his men first and of himself last. . . . I know of innumerable cases where he denied himself necessities to supply his men."

PRINCIPAL PUBLICATIONS OF ROBERT EDWIN PEARY

1887 A Reconnaissance of the Greenland Inland Ice, Bull. Am. Geogr. Soc., vol. 19, pp. 261-289.

1892 The North Greenland Expedition of 1891-92 ibid, vol. 24, pp. 536-558.

1893 (Mrs. Josephine Diebitsch Peary) My Arctic Journal: A Year Among Ice Fields and Eskimos, with an Account of the Great White Journey across Greenland, by Robert E. Peary, Contemporary Publishing Co. New York, p. 240.

1893 (Cyrus C. Adams) Lieutenant Peary's Arctic Work, Geogr. Jour., vol. 2, pp. 303-316.

1894 The Cape York Ironstone, Bull. Am. Geogr. Soc., vol. 26, pp. 427-488.

1895 Preliminary Report on the Arctic Expedition of 1893-94, Bull. Geogr. Club of Philadelphia, vol. 1, no. 3, pp. 121-123.

1896 Work in North Greenland in 1894-95, Bull. Am. Geogr. Soc., vol. 28, pp. 21-26.

1898 Journeys in North Greenland, Geogr. Jour., vol. 11, pp. 213-240.

1898 Northward Over the Great Ice, A Narrative of Life and Work Along the Shores and Upon the Interior Ice-Cap of Northern Greenland in the years 1886 and 1891-97. Maps, diagrams and about 800 illustrations, 2 vols., Stokes, New York, p. 521 and 625.

1903 Report of R. E. Peary, C.E., U.S.N., on Work Done in the Arctic in 1898-1902, Bull. Am. Geogr. Soc., vol. 35, pp. 496-534.

1903 Four Years' Arctic Exploration, 1898-1902, Geogr. Jour., vol. 22, pp. 646-672.

1904 North Polar Exploration: Field Work of the Peary Arctic Club, 1898-1902, Ann. Rept. Smith. Inst., 1903, pp. 427-457.

1904 Snowland Folk: The Eskimos, the Bears, the Dogs, the Muskoxen, and Other Dwellers of the Frozen North, illustrated, Stokes, New York, p. 97.

1905 Address of President Peary delivered at the Annual Meeting of the American Geographical Society, Bull. Am. Geogr. Soc., vol. 37, pp. 129-143.

1906 Commander Peary's Arctic Expedition, Bull. Am. Geogr. Soc., Vol. 38, pp. 683-686.

1907 Nearest the Pole, A Narrative of the Polar Expedition of the Peary Arctic Club in the S.S. Roosevelt, 1905-06, illustrated, Doubleday, Page, New York, p. xx and 411.

1909 The Discovery of the North Pole, First Report by Commander Robert E. Peary, U.S.N., April 6, 1909, Nat. Geogr. Mag., vol. 30, pp. 896-915.

1910 Peary Arctic Club Expedition to the North Pole 1908-1909, Geogr. Jour., vol. 36, pp. 129-148.

1910 The North Pole, Its Discovery in 1909 under the Auspices of the Peary Arctic Club, with an introduction by Theodore Roosevelt, map and 108 illustrations, Stokes, New York, pp. 273.

1917 Secrets of Polar Travel, Century Co., New York, illustrated, pp. 313.

1917 Command of the Air, address delivered before the Twentieth Annual Meeting of the American Academy of Political and Social Science, Govt. Printing Office, Washington, D. C., p. 10.

Annals of the Association of American Geographers
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MEMOIR OF SUMNER WEBSTER CUSHING

ELLSWORTH HUNTINGTON

Geography and mathematics are the only sciences which enter extensively into education at all ages. In mathematics the logical mode of procedure from the simple to the complex is so thoroughly established that it has ceased to be a problem. Geography, however, is still growing not only at the top, as in mathematics, but in every direction. Many of the new ideas of the most advanced investigators at once become a part of elementary education, as happened, for example, with the concept of cycles of youth, maturity, and old age. Because the subject is in such a state of flux there is grave danger of mistakes; the elementary teachers are often carried away by a laudable but mistaken enthusiasm for the new, even when it is far too mature for their pupils, while the advanced teacher is too elementary Hence, among the many and pressing needs of modern geography one of the greatest is men who know the whole range of the subject and can see it with the eyes of the eight-year old child, the college student, the teacher, and the highly trained investigator.

Sumner Webster Cushing was one of the few men who had this power of seeing geography with the eyes of all ages. He was fitted to do this by training and occupation, by scientific achievement, and by personality. To begin with training and occupation, Mr. Cushing was born in Norwell, Massachusetts, December 30, 1879, the son of Webster A. and Amanda Cushing. He was graduated from the Brockton High School and the State Normal School at Bridgewater. In 1903, after a two years' course at Harvard University, he received the degree of B.S. He then taught, in successive years, the subjects of science, mathematics, and physical geography in the high schools of Wakefield, Mass, Waterbury, Conn., and Providence, R. I. While in Providence he studied at Brown University and received his master's degree.

In 1907 he became the head of the geography department at the State Normal School in Salem, Mass. To quote from Mr. Pitman, principal of that school, "In addition to his classes in geography in the normal school, he supervised the work in the training school, made out a course of study for the guidance of the student teachers and the supervisors of the grades, and kept in close touch with the work of the children. His field trips and excursions to industrial plants added greatly to the interest in the subject both among the children and among the students in the normal school. His students will never forget the delightful trips to Devereux Beach, nor the more strenuous excursions devoted to tracing the course of Forest River. He was untiring in his plans to present subjects of general interest to the

entire school by lectures, lantern slides, and motion pictures. In every possible way he strove to make the subject of geography alive and to show its importance in understanding the trend of civilization. He succeeded to an unusual degree, for his students speak of him as a wonderful teacher." In addition to his work at Salem, Mr. Cushing taught geography at Wellesley College from 1911 to 1913, and gave summer courses at several universities—Illinois, 1910 and 1914; Columbia, 1912, and Miami, 1917. He was also on various committees of the Massachusetts State Board of Education and the National Council of Geography Teachers for the preparation of courses of study in elementary, high, and normal schools. Thus in both his education and his teaching Mr. Cushing came in contact with every phase of geographical education.

Mr. Cushing's career as a scientific investigator began with his attendance at the summer session at Harvard in 1907. As Professor Davis puts it: "A praiseworthy ambition to advance in his chosen science led him to spend the next summer in France, studying the Central Plateau with his former Harvard professors, W. M. Davis and D. W. Johnson. Similarly his vacation in 1909 was spent in an examination of the coastal features of Maine, during which he traveled in and out along the coast some 1500 miles. His statement of the results of this work before the Geological Conference at Harvard led to his securing a Sheldon travelling fellowship from the Harvard Graduate School, which enabled him, while on leave of absence from Salem, to visit India in 1910-11, for the investigation of a special geographical problem in the region of Madras. His report upon this problem, "The East Coast of India," presented at a meeting of the Association of American Geographers in 1911, attracted highly favorable notice as far and away superior to any previous description of the Madras coast. Its publication at once gave him an assured position as a professional geographer." Later work on Japan and New England, and upon many problems in commercial and industrial geography confirmed this position.

In his personal relations Mr. Cushing was at his best among his students. There he lost a certain shy reserve which sometimes partly concealed a really remarkable sweetness of disposition. When he came into intimate contact with his fellow geographers, as he did, for example, during the Transcontinental Excursion under the auspices of the American Geographical Society in 1912, he was revealed as a man of most genial sympathies, unusual courtesy and great modesty, with decided opinions but holding them in the true spirit of humility which is ready to acknowledge mistakes and profit by the advice and experience of others. That excursion broadened him greatly, as did his marriage in 1913 to Miss Frances B. Deane. She had been a teacher of history in the Salem Normal School, and her historical knowledge and

literary ability were a great help to Mr. Cushing. Of even more importance was the fact that she strengthened his confidence in his own powers, for he often underrated himself. Another experience which had a similar broadening and strengthening effect was a year's service as Captain in the Military Intelligence Division of the General Staff in Washington, from July, 1918, to July, 1919. As General Churchill, his chief, well said, he left behind him "a record of marked ability, and fine devotion to duty. He endeared himself to all his associates."

In Mr. Cushing's own opinion all his work up to about 1914 was merely preparation for his great life purpose. That purpose was to help create the right relation between geographical research and teaching, and between the teaching in one stage of education and another. Most of his program to this end was perforce left unfinished. Judging by his articles and addresses and especially by his phenomenal success in inspiring normal school students and elementary teachers, his projected book on the teaching of geography and the use of problems would have marked an important step toward the goal of satisfactory geographical teaching. Something of its character may be judged from a "Teacher's Manual of Geography for Grades VII and VIII," which was distributed broadcast by the Massachusetts State Board of Education and for which there was a great demand in other states. Although the Manual was ostensibly prepared by a committee, Mr. Cushing was the moving spirit, and the ideas and methods of the book are largely his. Another place where Mr. Cushing's educational ideas are firmly embedded is in the "Principles of Human Geography," of which he was joint author with the present biographer. To that book, which unfortunately did not appear until after his death, Mr. Cushing contributed the major part of whatever pedagogical value it may have. Another joint book, "Commercial and Industrial Geography," was nearly completed at the time of Mr. Cushing's death. To this he contributed the general plan, the method of presentation, and a large share of the text.

In all his work Mr. Cushing insisted first on absolute accuracy, for he was supremely truthful. He also insisted on orderliness, and on the idea that the mind of the student must work with that of the teacher. It is most impressive to hear his former pupils say, "Mr. Cushing made me think of that." He put his mark on his students and all who came in close contact with him because of his enthusiasm, for above all things he was an enthusiast. His enthusiasm was not merely for geography nor for teaching, but for the right relation of the two. His death leaves uncompleted a great piece of work for which he possessed a rare training. His sympathetic personality was fast making that training most effective in bridging the gap between the leaders of scientific investigation and the teachers through whom geography filters down into the common consciousness of mankind.

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MEMOIR OF FREDERIC PUTNAM GULLIVER

WILLIAM MORRIS DAVIS

Frederic Putnam Gulliver was born at Norwich, Connecticut, on August 30, 1865, the son of Dr. Daniel Francis and Mary (Strong) Gulliver, the fifth of eight children, of whom four survive him. His father was a native of Boston, a graduate of Yale in 1848, and of the Jefferson Medical College in Philadelphia a few years later; on account of ill-health he early gave up the practice of his profession and devoted himself to farming and stock raising. Gulliver's mother was descended from some of the original settlers of Norwich, including Huntingtons, Edgertons and Traceys; her family always lived in the town and city since its foundation. Through her, her son is related to Ellsworth Huntington, this being one of the few cases of cousinship among our members.

After preparatory schooling at the Norwich Free Academy, Gulliver entered the Massachusetts Institute of Technology in 1883 and studied mining engineering until 1886; then having acquired a considerable skill in topographic surveying and without waiting for a degree, he secured an appointment as field assistant in the topographic branch of the United States Geological Survey, and was promoted to the rank of topographer in 1889. The districts he surveyed were all in eastern states. His ability to " see country " and to portray it upon maps of different scales led to his being placed in charge of field parties, in which some of the assistants were double his age and were receiving twice his salary. This work gave him expertness, but did not offer satisfactory prospects of advancement or sufficient scope for his scientific interests; it led him, however, to feel the need of further education and especially of a fuller knowledge of the features of the land upon which his work had been performed; but the immediate cause of his resignation from the Survey in 1891 was ill-health, apparently induced by something like a sunstroke. When he became well enough for study, he concluded that his interests were on the scientific rather than the topographic side of geography, and definitely adopted teaching as his aim. In preparation for this career, he decided to study at Harvard, where he was admitted to advanced standing in the College in 1892 and received the degree of A. B. with the class of 1893. Then wishing to equip himself still more fully in his chosen subjects of geology and geography, he registered in the Graduate School, where he received the degrees of A. M. in 1894, and of Ph. D. in 1896. His genial nature and his sincere interest in his studies made him welcome among students and teachers alike.

During these years of graduate study, Gulliver's topographic skill was shown in the construction of two models of a well developed

glacial sand plain and its feeding esker in Newtonville, near Boston; one model presented the actual form of these features on the basis of original sketch surveys; the other added the supposed attitude of the ice sheet while the feeding esker and the outwashed delta plain were in process of formation at its slowly retreating margin. These models served as the basis of Gulliver's first published article.

It was also during this period of graduate study that Gulliver spent the summer of 1894 as assistant geologist on the U. S. Geological Survey, when he had the good fortune to work under G. K. Gilbert on the Apishapa quadrangle in Colorado, the Folio of which bears his name with others. Owing to his previous experience in surveying, he was largely occupied in making plane-table maps of special areas where the structure was too complicated to be shown on the base-map scale, or where the base map was unusually inaccurate. He also measured sections and computed the thickness of formations and traced their boundaries. He is described by an associate of that summer as an interesting companion in camp, full of stories, and always ready to discuss problems and theories. Mr. Gilbert, in a letter written during the summer, said of him, "He is a charming fellow, gentle, cultured, able and in every way companionable." One of the results of this season's field work was a joint paper with Gilbert on "Tepee buttes," or wigwam-like residual knobs that surmount the degraded plains where localized accumulations of fossil shells resist erosion.

During other vacation months Gulliver examined the district around his home city of Norwich, Connecticut, and reached the conclusion that, after the general peneplanation of the region as recorded in the uplands, several subordinate low-grade surfaces of much smaller area were produced during pauses in the uplift of the region; thus he in a measure anticipated the more definite results later reached by Barrell for the same state.

For the last two years of his graduate study, Gulliver was closely associated with the writer in an investigation of "Shoreline Topography," which he had chosen for a thesis and to which he gave the most persevering and successful attention. He made a thorough review of all previous work on this attractive subject, devised a general and comprehensive scheme of treatment for it, and applied the scheme assiduously in the description of actual shore lines as represented on large-scape maps and charts of many parts of the world. The scheme took account of a multitude of detailed features which follow from the general principle that the forms of a coast are dependent, first, on a movement of the earth crust or a variation of ocean level, whereby a previous land surface is partly submerged or a previous sea bottom is partly emerged; and second, on the fairly systematic sequence of changes that a new shore line thus originated will suffer as determined by its structure and by the nature of the agencies operating upon it.

It was in this connection that he introduced the excellent terms, initial, sequential, and ultimate, as designating the first, intermediate, and final stages of not only the cycle of marine erosion under which coastal forms are produced, but of all cycles of land erosion by whatever agency. He also showed clearly that such terms as young, mature, and old, which apply so well to successive stages in the cycle of subaerial erosion, apply equally well to the cycle of marine erosion; further, that every change in the attitude of a coast or in the level of the ocean must, in lesser or greater degree, interrupt the progress of the cycle of shoreline development previously current and introduce a new cycle; hence the old forms that would theoretically characterize the far advanced stages of the marine cycle should be and actually are less frequently found than the old forms of subaerial erosion in continental interiors, where erosional processes are less sensitive to changes of land attitude. While these studies were in progress, he made a special examination of a peculiar group of littoral forms which result from the interaction of eddying shore currents, and which he called "cuspate forelands." They formed the subject of a valuable article which appeared in the Bulletin of the Geological Society of America. His thesis, published three years later in the Proceedings of the American Academy of Arts and Sciences at Boston, has been frequently and favorably cited; it contains a large store of examples, taken chiefly from maps and charts, and classified according to his systematic scheme for the ready illustration of shoreline forms.

On completing his graduate studies, Gulliver received a Harvard Travelling fellowship and passed a year in Europe, where he spent the fall semester at the University of Berlin under von Richthofen, and the spring semester at the University of Vienna under Penick; he also visited a number of other universities for the purpose of consulting their professors of geography on his special subject, and he examined certain coastal districts that were of special interest as exhibiting typical examples of one stage or another in shoreline development. A large cuspate foreland, known as Dungeness, on the southeast coast of England was examined in detail and described in the Geographical Journal of the Royal Geographical Society with more appreciative recognition of its form and its origin than it had previously received in print. This foreland had attracted his attention because the review that he had made of coastal charts had discovered two other similar forelands of the same name, one in the Straits of Magellan, the other in Puget Sound, which had evidently been so designated by British navigators because of their resemblance to the home type. His letters during this period of travel and observation were warmly expressive of the courtesy with which he was received in his university visits, and of the stimulation gained by his personal and coastal experiences.

After returning from Europe in 1897, he was appointed a master at St. Mark's School, in Southborough, Massachusetts, where he remained eight years, teaching physiography, meteorology and botany to the older boys, and leading the younger boys into elementary general science, largely by outdoor lessons and field observation. His frank enthusiasm and good fellowship gained him the affectionate regard of his pupils, but his gentle nature was little fitted to restrain the unruly behavior of some of them, and his classes were not noted for strict discipline. One of his entertainments during this period was pruning of the trees in a neighboring apple orchard which an old-fashioned farmer had left to their own habits of growth. His shore line studies were continued in the summers, especially regarding the island of Nantucket, of which he published a brief account; in 1904 he contributed a paper on "Island Tying" to the International Geographic Congress held in Washington.

After resigning from St. Mark's, Gulliver resided chiefly at his old family home in Norwich. For the remainder of his life, it seemed as if uncertainty regarding his health discouraged his seeking formal engagements or entering upon large undertakings; but his interest having been aroused in the improvement of geographical teaching in the public schools, he gave much time to the planning and preparation of a text book on the geography of a city, which, as many school children attend city schools, should serve as a beginning for the extension of rational geographical ideas to other parts of the world; this task, however, was not carried to completion. In 1909 he served as chairman of the Historical Committee for the 250th anniversary celebration of the founding of Norwich, and was appointed editor of the commemorative volume, but this duty he was unable to fulfil. He later accepted appointment as geographer on a State Commission in Pennsylvania, charged with the suppression of a blight by which the chestnut trees of that and the adjoining states were nearly exterminated; but his health was then failing and he died in Philadelphia, on February 8, 1919.

During these later years of his life Gulliver's devotion to geographical and geological science led him to continue the relations already formed with others of similar tastes. Having taken membership in the American Association for the Advancement of Science several years before, he served as secretary for Section E, Geology and Geography, in 1902, 1907-09 and 1911. He was also a member of the Geological Society of America and of the Association of American Geographers, and was especially interested and active in the meetings of the latter organization.

It is a misfortune for geographical science in America that one whose preparatory studies were of so great promise had not longer life and greater strength for their full extension.

BIBLIOGRAPHY

Prepared by the Librarian, U. S. Geological Survey

The Newtonville sand plain [Mass.]. Journal of Geology, vol. 1, pp. 803-812, 1893. Abstracts, American Association for the Advancement of Science, Proceedings, vol. 42, p. 178, 1894; (with discussion) American Geologist, vol. 12, p. 177, 1893.

Tidal sand cusps (abstract). Science, new series, vol. 2, pp. 705-706, 1895.

(with Gilbert G. K.) Tepee buttes [Colorado]. Geological Society of America, Bull. 6, pp. 333-342, map, 1895. Abstract, Science, new series, vol. 1, p. 59, 1895.

Cuspate forelands. Geological Society of America, Bull. 7, pp. 399-422, 1896. Abstracts, American Geologist, vol. 17, p. 98, 1896; Science, new series, vol. 3, p. 51, 1896.

Types of lowland coasts. Science, new series, vol. 3, p. 128, 1896.

Tidal scour (abstract). Science, new series, vol. 3, pp. 570-571, 1896.

Post-Cretaceous grade plains in southern New England (abstract). American Geologist, vol. 18, p. 231, 1896.

Shoreline topography. American Academy of Arts and Sciences, Proceedings, vol. 34, pp. 149-258, 1899. Abstract under title, Classification of coastal forms, American Geologist, vol. 22, p. 253, 1898; Science, new series, vol. 8, p. 466, 1898; Geological Society of America, Bull. 10, p. 19, 1899.

Thames River terraces in Connecticut. Geological Society of America, Bull. 10, pp. 492-495, 1900. Abstract, American Geologist, vol. 23, p. 104, 1899. Abstract, Science, new series, vol. 9, p. 144, 1899.

Cuttyhunk Island [Mass.] (abstract). Geological Society of America, Bull. 13, p. 538, 1903.

Nantucket shore lines Geological Society of America, Bull. 14, pp. 555-556, Bull. 15, pp. 507-522, 1904. Abstract, Science, new series, vol. 19, p. 531, 1904.

Island tying. International Geographical Congress, VIII, Rept, pp. 146-149, 1905.

Sudbury Basin shore lines (abstract). Science, new series, vol. 22, pp. 334-336, 1905.

Brewsters Neck, Connecticut (abstract). Science, new series, vol. 24, pp. 368-369, 1906; American Association for the Advancement of Science, Proceedings, vol. 56-7, pp. 268-269, 1907.

The American Association for the Advancement of Science: Summer meetings, Section E—Geology and geography. Science, new series, vol. 26, pp. 397-404, 1907.

Ice present during the formation of glacial terraces (abstract). Science, new series, vol. 25, pp. 770-771, 1907; Geological Society of America, Bull. 18, pp. 640-641, 1908.

Graded surfaces (abstract). Geological Society of America, Bull. 18, pp. 609-610, 1908.

Nantucket shore lines, IV (abstract). Science, new series, vol. 29, p. 633, 1909. Geological Society of America, Bull. 20, p. 670, 1910.

The American Association for the Advancement of Science: Section E, Geology and Geography [Baltimore, December, 1908]. Science, new series, vol. 29, pp. 747-757, 1909.

Geology and geography at the Boston-Cambridge meeting [meeting of Section E of the American Association for the Advancement of Science, December, 1909]. Science, new series, vol. 32, pp. 124-128, 1910.

Wauwinet-Coscata tombolo, Nantucket,Mass. (abstract). British Association for the Advancement of Science, Report 79th Meeting, p. 536, 1910.

Delta form and structure of the Thames River terraces, Conn. (abstract). Association of American Geographers, Annals, vol. 1, p. 536, 1911.

ANNALS OF THE ASSOCIATION OF AMERICAN GEOGRAPHERS
Volume XI, p. 117

MEMOIR OF WILLIAM CHURCHILL

CYRUS C. ADAMS

William Churchill was born in Brooklyn, N. Y. on October 5, 1859 and died in Washington, D. C., on June 9, 1920. Churchill was a philologist primarily. His life for several years in Melanesia, as Consul General at Samoa and Tonga led him into the study of ethnology and anthropology and gave him unusual opportunities for following his native interest.

This sojourn and study resulted in many ethnological and philological publications and earned for him honorary membership in several foreign learned societies. He felt in sympathy with the Pacific Islands, he looked backward to his life there with deep appreciation of his opportunities and looked forward to the opportunity of returning and carrying on what he considered his real life work and interest.

Necessity however caused him to devote much of his time to writing and editing for a living. For thirteen years he was a departmental editor of the New York Sun and during this period he contributed regularly and fairly abundantly to the Bulletin of the American Geographical Society.

On his infrequent appearance on the program of the Association he presented stimulating and interesting papers in a field which he alone represented in our membership. His interest being in life and life conditions he had little sympathy with the work of those who found their incentive for scientific work in the physical aspects of geography.

Owing to his first hand acquaintance with peoples, languages and regions of Melanesia, his services were of great value to the Government which he served during the war through the Committee on Public Information.

"Not only did he have what might be called an old-fashioned classical education but he was a natural born scholar, who pursued investigations in the language and ethnology of the Pacific region with the keenest enthusiasm during many years of newspaper work. His opportunity came only when his work was recognized by the Carnegie Institution, where he obtained support for a broad project of investigation into studies on the migrations of Pacific peoples in combination with Pacific philology. He had an almost boyish view of life and an intense interest in his friends and professional acquaintances, every one of whom treasures letters which he wrote under many different circumstances ranging from the happiest to the saddest. He had extraordinary powers in the way of focusing his attention upon technical problems of great complexity and represented a high type of scholarship exceedingly rare in this country."

TITLES AND ABSTRACTS OF PAPERS

Chicago, 1920

Herbert E. Gregory.

Presidential Address:—Geographic Basis of the Political Problems of the Pacific—Read by Title.

Cyrus C. Adams.

Memorial of William Churchill. Printed in full herewith.

Esther S. Anderson (Introduced by N. A. Bengston).

Population Changes in Nebraska Since 1880.

Changes in population of typical Nebraska counties since 1880 show the effectiveness of geographic controls. Types of changes have been dissimilar within the three physiographic regions, whereas within each division a general similarity is shown. The influences which have caused the variations are (1) climatic factors; (2) the nearness to railroads; (3) the introduction of drought resistant crops in the less humid regions; (4) the introduction of irrigation in western Nebraska; (5) adaptation of methods of cultivation; (6) the extension of small grain farming in eastern Nebraska; and (7) the use of more efficient machinery.

Wallace W. Atwood.

The Development of Productive Scholarship Among American Geographers.

In the development of productive scholarship in geology and the promotion of that great science the Federal Government and many of the state governments have furnished opportunities to the men entering that field of study to devote all of their time to research and the preparation of material for publication. Many geologists who have been engaged in educational work have had ample opportunity during the summer season to carry on actual research work and from time to time to publish their results. These conditions have, I believe, been essential to the development of productive scholarship in geology.

Geography needs a similar support and a similar productive scholarship in America. If geographers are given an equal opportunity will they not produce equally valuable results; will there not come to be in this country a body of men and women who have a first-hand knowledge of the distant parts of the world, and should not such members of the profession produce American literature on geography which is very greatly needed? For many people geography has come to mean a study of the ever-changing adaptations of people to their environment and it would therefore appear to be especially important that the

students of geography keep in close touch with the actual conditions in the various parts of the world, and have sufficient time and support for the development of productive scholarship.

Zonia Baber (Introduced by G. J. Miller).

The Distribution of Sunlight and Moonlight on the Earth.

The "Lands of Midnight Sun" and day-night moon are the critical areas of distribution of light from the point of view of life.

Since the variation in the length of the period of continuous light of the sun, or of the moon, depends upon the apparent declination of the sun and of the moon, it is evident that the critical area of sunlight remains approximately the same.

But the critical areas of moonlight must vary in size depending upon the place in the "Metonic cycle," for during the Metonic cycle, of about 19 years, the moon's turning points vary from latitude 18° 9′ North and South, to latitude 28° 44′ North and South. In the year 1904 of the present lunar cycle, the moon turned at latitude 18° 9′ North and South making a zone that saw the moon in the zenith of about 36° 18′. This zone increased in width from 1904 until 1913 when it reached a breadth of 57° 28′. After reaching the greatest extension of the moon's vertical rays, the lunar tropics moved equatorward. This movement will continue until about 1923 when the poleward movement will again begin.

During the month of December 1920 the lunar polar area extended 19° 29′ from the poles to latitude 70° 33′. The limits of these regions have but one day-night of continuous moonlight, but the centers have about 14 day-nights of moon-light.

Oliver E. Baker.

The Importance and Permanence of the Physical Factors in Determining the Utilization of Land for Agricultural and Forest Production. Printed in full herewith.

Louis A. Bauer.

The Status of the General Magnetic Survey of the Earth.

The paper first gave a brief summary of the work in investigations of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington, during the period 1904 to 1920, with reference to the accomplishment of the task assigned to the Department—the general magnetic survey of the Earth. A brief account was also given of the work done during the same period by cooperating organizations and institutions.

Particular reference was made to the scientific and practical prob-

lems of ocean magnetic surveys, and it was shown how far the solution of these problems has been advanced. The slides showed the status of ocean magnetic surveys before the work of the Department of Terrestrial Magnetism and the progress since then.

It was further shown how the work of the Department of Terrestrial Magnetism has been planned so that both the theoretical and practical aspects of a magnetic survey of the Earth would receive adequate attention and that actual progress be made towards the solution of the outstanding greater problems pertaining to the theory and origin of the Earth's magnetism and of its never ceasing changes. In conclusion, brief statements were made of other scientific work accomplished aboard the magnetic survey vessel operated by the Department of Terrestrial Magnetism (detection of areas of local magnetic disturbance; atmospheric electricity; atmospheric refraction; meteorology; ocean currents; geographical discoveries).

N. A. Bengston.

Notes on the Geography of Honduras.

The topography of Honduras is characterized by (a) narrow coastal plains; (b) steep mountain fronts facing seaward; (c) interior mountain ranges that reach altitudes of 4000-8000 feet; (d) two series of terraces; and (e) dissected peneplains.

The climate varies with the topography and the terms rainy and dry seasons have distinct local applications. Industrial development has been largely concentrated where topographic barriers to transportation were wanting. Back of such barriers but a few miles is a people living as did those of four centuries ago in the same place. Future railway building is forecasted by the line of least topographic resistance —the great graben-like depression through the Cordilleras of the country.

Charles F. Brooks.

Cold Surf with Off-Shore Winds.

Reports of unusually cold water along the middle and north Atlantic coast of the United States during July and August, 1920, led to an examination of the wind and cloudiness records during these and immediately preceding months. It was to be expected that should there have been deficient sunshine and an unusual persistence of off-shore winds the surface water would not have been heated as much as usual, and it would have been blown rather rapidly out to sea, only to be replaced by the much colder water from below. Aside from the effects of an unusually cloudy June at Boston and a rather cloudy August at Atlantic City, the solar heating of the water was probably normal.

The wind conditions, however, stand out as the obvious cause of the coldness of the shore water. The wind at Atlantic City was more persistently off-shore in June and July than in these two months in any year since 1912. Similarly, the wind at Boston was strongly off-shore; in July there was five times as much off-shore as on-shore wind.

Robert M. Brown.

Census Maps of the United States, with Some Suggestions for Improvement for Use in Geography.—Read by Title.

Henry C. Cowles.

Ecology and Geographic Boundaries.

Henry J. Cox.

Rise in Temperature on Mountain Summits Earlier than on Valley Floors.

In a research conducted in the North Carolina mountains, by the Weather Bureau, a study was made of early rises in temperature at the mountain summits. Frequent instances are noted of rise at the summit during the night time before that at the base, and an occasional instance of rise at the summit when the temperature was still falling at the base.

These are most pronounced on isolated peaks, and especially those that have no relatively high mountains or plateaus immediately to the east or south which may shut off the winds from those directions. As a result of this phenomenon, inversions in temperature have been noted ranging from 10° to 30°. However, the rise seldom begins more than 10 hours earlier at the summits, and there are no instances of rises 24 hours in advance, as noted by McLeod in his studies of Mount Royal, Montreal, and by Clayton in his studies of Blue Hill. This is because the Carolina mountain region is not in any of the principal storm tracks, as are both Mount Royal and Blue Hill, where the influence of approaching depressions are earlier felt at a high elevation.

D. H. Davis (Introduced by Carl O. Sauer).

Significant Geographic Problems of the Outwash Plains of Southern Michigan.

Outside of the area of the French settlement around Detroit, the first portions of the lower peninsula of Michigan to be occupied were the outwash plains of the southwest. These level, well drained and easily cultivated plains, with their open forest and many small prairies, proved attractive to the pioneer. Little or no clearing was necessary and the soil yielded abundant crops with small effort. Small towns with saw mills and flour mills sprang up to meet the needs of the agri-

cultural population. Roads were few and poor, railroads unknown. Each community, with its village center, was almost if not quite self sufficient.

Since the advent of the railroad, conditions have changed. The towns with strategic locations have shown a steady growth and have developed along industrial lines; the purely community centers, out of touch with main lines of transportation, have shown a steady and persistent decline in population, both relatively and numerically. The early adjustment has disappeared and no readjustment has occurred.

The farming area also suffers from a similar mal-adjustment. The light soil, with its originally sufficient humus content, is now largely incapable of raising satisfactory crops under present farm practice. Each farmer still raises a great variety of crops, not taking into account the great changes in the economic activities of the area, the alteration in transportation facilities and the shifting tendencies of progressive farm practice.

Here we have an area in which a very rapid and satisfactory adjustment to early conditions occurred, but one in which the shift to meet changing economic conditions has not taken place except in very small measure. The population is increasing, but the increase is confined to the industrial centers; the rural population and that of the small towns have shown a persistent and steady decline for the past forty years in the face of the better market for farm products which is afforded by the industrial centers.

Wherein does the future lie for those sections which reached the crest of their wave of prosperity between 1870 and 1880? As to the small town, off main lines of transportation, it is probably doomed and will become of less and less importance and contain fewer inhabitants. The farming area, with its better markets in immediate proximity to the farm, will be obliged to adjust its crops to changed soil conditions, to meet the demands of the industrial centers and the competition of other agricultural areas. Increasing industrialization of the area is bound to occur and with this should go increased prosperity with rational utilization of the land.

W. M. Davis.

Intermont Basins—Read by Title.

Memoir of Frederic P. Gulliver. Printed in full herewith.

Richard E. Dodge.

Geographic Factors in Dairy Farming in Southern New England.

The paper emphasized the change of values of geographic relationships with the changes in New England agriculture. In the earlier days farmers were nearly self sufficient and relied but little upon

outside sources of cattle feed or outside markets. With the development of industrial cities dairy farmers turned from butter and cheese making to the selling of whole milk. Grain acreage decreased, dairy cattle took the place of beef cattle and concentrates became necessary in the dairy ration. This made the area dependent on the west and south for necessary grain for cattle and horse feeding.

With the recent rapid increase in freight rates, grain rose so rapidly in price that farmers in many sections turned again to raising more grain and better hay. The cost of production of milk was thus lowered and the success of new methods warrants our expecting New England dairy farming soon becoming more self sufficient than it has been for the last forty years.

Oliver L. Fassig.

The Trade Winds and Anti-Trades of Porto Rico.

The paper presented an analysis of the trade winds over Porto Rico, based upon daily balloon observations. Charts indicated variations in velocity and direction.

Progress in the Organization of a Climatological Service of the West Indies.

A summary of the purposes of a climatological service to embrace all the islands of the West Indies and portions of the coasts of Central and South America.

V. C. Finch.

The Significance of Vegetable Oils in the Economic Development of the Tropics.

The paper summarized the recent development of commerce in vegetable oils, the present and possible future sources and demand.

F. W. Frostic (Introduced by Carl O. Sauer).

A Geographic Study of the Saginaw Valley as an Area of Gentle Relief.—Read by Title.

W. H. Hobbs.

A Significant Contrast Between the Atlantic and Pacific Coastal Regions.

The recent study of earthquakes from remote stations has proven conclusively that the larger movements of the earth's crust which are now going on have taken place near, though largely inside, the borders of the Pacific Ocean, though there is a strong subordinate zone which

follows the twin plane of the intercontinental seas. Outside these zones the lithosphere surface may be described by contrast as in repose. The contrasted conditions for the Atlantic and Pacific regions are therefore striking.

The process of marine degradation which shapes the continental shelf and, in case of rapid uplift, yields coast terraces, supplies us with a measure for the rate of crustal deformations. Wherever uplift goes on slowly, as it does about the margins of the Atlantic, the treads of the coast terraces are found to be both broad and elaborately eroded by stream action, and the average angle of the terraces is small. Cuestas may be developed. Wherever, on the contrary, uplift is going on rapidly, as it is on the borders of the Pacific area, the treads of coast terraces are narrow and the risers relatively high, the surface of the treads is smooth and but slightly affected by river erosion, and the average angle of the terrace series will be correspondingly large.

Memorial of Robert E. Peary—Printed in full herewith.

R. S. Holway.

Stream and Ocean Terraces in Relation to Recent Earth Movements.

The investigation has been undertaken to determine, if possible, the character and relative amount of recent earth movements in central California over an area approximately 150 by 60 miles in extent including the entire width of the Coast Ranges from the great interior valley to the sea. Santa Cruz marks roughly the northwestern corner of the region being studied.

The measurement of the height of terraces, either stream or ocean, requires the definition of both "terrace level" and baselevel and also the determination of the physical features that identify these levels. Baselevel for ocean terraces is of course sea level, with its usual difficulties of determination, including probably for the upper terraces the question of variation during the glacial period. Baselevel for stream terraces is taken at the low water level of the stream, provided that the stream at the location of the terrace is meandering and very definitely cutting laterally and not noticeably deepening its channel. Such a baselevel is constantly rising in absolute height toward the source of the river. A terrace above a youthful gorge evidently has no determinable height. Theoretically this is also the case with an ocean terrace on an exposed shore, if the sea at that point has not yet made a perceptible cut in the land. "Terrace level" is taken at the surface of corrosion marked by beveled strata in order to eliminate alluvial fill. With ocean terraces this level is measured at the rear of the terrace as the surface of corrosion has always a seaward slope.

With stream terraces the level is taken wherever the beveled strata are exposed for the valley floor of a stream cutting laterally is practically level on a line normal to the axis of the valley.

In some instances stream terraces in the lower course of a river merge into ocean terraces making a self evident correlation of the two. With streams far inland, correlation with ocean terraces is made on the similarity of height above their respective baselevels and on the approximate agreement in the time of standstill of the land during lateral corrosion, as indicated by the relative widths of the terraces.

Thus far in the investigation the data accumulated seem to indicate that at various absolute elevations above sea and in widely separated localities there exist series of three or four stream terraces with a total vertical range of 600—800 feet that may be correlated with each other and with a series of ocean terraces. In some adjoining mountain blocks there seems to be a lack of such agreement in terrace levels. The conclusion that the area being studied has moved substantially as a unit in recent times is suggested but not asserted at the present stage of the investigation.

Ellsworth Huntington.

Memorial of Sumner W. Cushing—Printed in full herewith.

Mark Jefferson.

Chile: A Land Where Immigrants Need Not Apply.

Much of Chile's 290,000 square miles is little available for homes for men. The arid deserts of the north, the rain-soaked forests of the south, and the rough Andine slopes which fill the eastern half of the country for the whole three thousand miles of its length subtract so much from the total area of the country that its 13 people per square mile becomes 156 people to the square mile of usable territory. That is why Chilean agriculture is intensive, with yields per acre greater than elsewhere in America; why the peasant is ill paid, ill fed, landless, and wretched; why immigrants are placed on the land only by ejecting the people of the country, and why fifty years of government-fostered immigration have not brought fifty thousand people to Chile.

W. L. G. Joerg.

Bering's Two Expeditions to Determine the Relation of Asia to America.

A discussion of Bering's two voyages, 1725-30 and 1733-41, in the light of new material, recently found by Professor F. A. Golder in the Russian government archives.

A. K. Lobeck (Introduced by R. H. Whitbeck).

Physiography and Man in Porto Rico.

Porto Rico may be divided into five types of physiographic elements: (1) a central upland; (2) mountain groups above the upland; (3) a piedmont upland at the base of the higher central area; (4) a coastal plain; (5) broad alluvial-covered river flood plains or "playas" near sea level. In the central upland area coffee growing is the most important industry. The mountain groups are wild and uncultivated and are occupied by national forests. The piedmont upland which borders the northern coast supports sugar fields and tobacco. The coastal plain is given over to fruit raising, especially grape fruit and pineapples. In the great playa planis sugar cane is the important crop, every available square foot being devoted to that purpose.

D. T. MacDougall (By Invitation of Council).

The Relation of Plants to New Habitats.

The plan of the implied investigations included the establishment of small experimental areas in four places in which the environmental complexes were widely different, the introduction of species from outside localities, and the exchange of species native to the localities of the experimental plots.

The following statements may be made as to the conditions of dissemination of plants and barriers to distribution:

1. The dissemination of species toward lower levels takes place with facility as the change is from low to higher temperatures, and the actual transportation of seeds or propagules would be aided by air-currents, gravity as making for earth and rock slides, and streams of water. The isolated mountain and desert complexes, however, offer a range of temperatures beyond the capacity for adaptation of all but a few species.

2. An action the reverse of this may be found in the distribution of some of the opuntias; these are preeminently characteristic of the lowlands and of the deserts, but a half dozen species, are represented in the region of the oaks as high as 1,700 meters, while one species extends beyond the oaks and is found among the pines in rocks at 2,300 meters. It was discovered, however, that animals, probably rodents or rabbits, operate a barrage against the movement of other opuntias upward on the mountain slopes, as became evident by some experimental tests in the Mohave desert of California and by repeated introductions at the Xeromontane plantation.

3. It is rarely possible to ascribe the stoppage or restriction of a species to the direct and simple action of a single physical agency.

The actual effect upon one species of defective humidity, low or high temperatures, soil moisture, and other environic components, is dependent upon the intensity or degree of the others together with an allowance for rapidity of variation in these factors as well as time or duration of exposure.

4. Species from cool regions may be more easily established in warm places than the reverse, and montane plants may come to the seashore more easily than the plants of maritime zones may spread over a mountain.

5. Dissemination movements are seen to be freer from regions presenting climatic extremes to more equable climates, as is amply illustrated by the success of so many species from the Atlantic States and Arizona highlands on the Pacific seashore. Possibly the occurrence of the succulent *Opuntia* in Saskatchewan may be considered as an example of this as the predominant feature in dissemination.

6. Not all groups of forms move and adapt themselves to new habitats with the same facility. Thus the species characteristic of desert regions represent an extreme development toward succulence and xerophytism suitable for existence with a lessened water supply, and the retracement of the long way of morphogenic alteration by such species is all but impossible. On the other hand, many mesophytic plants show direct or individual alterations by which they pass into arid areas and maintain themselves for extended periods.

7. The experiments again make it plain that the habitat in which a plant may be found or in which it may have originated may not furnish the most favorable environmental complex, as amply illustrated by the behavior of species that have become weeds. In other words, the fitness of a species for native habitat may not be so close as its fitness for other as yet untried conditions.

George R. Mansfield.

The Geography of Part of Southeastern Idaho—Read by Title.

A mountainous region comprising seven quadrangles with a total area of about 2,200 square miles in the very southeastern corner of Idaho with narrow strips of Utah and Wyoming, has been studied by the United States Geological Survey as a part of its investigation of the western phosphate field. The region lies chiefly in the northern Rocky Mountain province but includes also part of the Basin-and-Range province, both areas being interfingered along their borders with projections of the Snake River lava plain.

The region is underlain by complexly folded and faulted sedimentary rocks, the surface features of which have been determined by later, intermittent uplift, with some warping or gentle folding, and by a series of partial erosion cycles or episodes, of which at least

nine may be distinguished. Normal erosion has been the principal factor in the production of present topography, though climatic change has exercised a clearly distinguishable influence especially in the later stages of topographic development. Lava extrusions both within and without the region have also played an important part in the production of the present surface features.

The semi-arid climate (13-14 inches rainfall) and the prevailing westerly winds exercise a strong control on the distribution of the vegetation. The valley bottoms and windward slopes (5,800 to 7,500 or more feet in elevation), are generally grass or sage-covered. Leeward and higher windward slopes (7,500 to 10,000 feet in elevation) are generally well wooded with aspen, lodge pole pine, Douglas fir and other trees, the last two named being important sources of lumber.

Agriculture and grazing are the chief industries, though phosphate mining promises to assume increasing importance. Frosts, which may occur during any summer month, render the valley bottoms unfit for cultivation. Along the sides of the valleys on slightly higher ground crops of grain, hay and potatoes are raised chiefly under irrigation, but dry farming is assuming increasing importance.

Lawrence Martin.

The Armenian Frontier—Read by Title.

K. C. McMurry (Introduced by H. H. Barrows).

Nashville and the Central Basin of Tennessee.

The growth of Nashville during the past forty years has been slower than that of most of the other important southern cities. Geographic factors have largely controlled this growth. Nashville is the center of the Central Basin of Tennessee, a limestone area very similar to the Bluegrass of Kentucky, almost entirely agricultural and undoubtedly the most productive division of the state.

Nashville is largely a central market and distributing center rather than a manufacturing city. The greater part of its business is with the Basin. Therefore the agricultural growth of the basin is an important controlling factor in the growth of Nashville.

During the past fifty years the agricultural expansion of the Central Basin has been exceedingly slow. Conditions at present are little changed from those of 1880. The same products are raised in much the same way as formerly and a large percentage of the area remains unproductive. In some respects the land has deteriorated rather than advanced. The growth of Nashville has been held back by the static conditions in its most important tributary area.

A new type of agriculture has been developing rapidly in the past

ten years. Dairying and cattle raising are increasing rapidly. A new adaptation is being made to a favorable environment. It is certain that as this type of agriculture increases a much higher productivity and buying power will be developed in the Basin. The result will be a corresponding increase in the prosperity and size of Nashville.

S. J. Novakovsky (Introduced by Ellsworth Huntington).

Geographical Regions of the Fisheries of Asiatic Russia.

The importance of fisheries in economical life of Russia and Siberia. The amount of fish consumed by the population of Siberia.

General conditions of fisheries in Asiatic-Russia.

Principal geographical regions of fisheries in Asiatic-Russia: 1) Lena-Kolyma; 2) Lake Baikal; 3) Yenise; 4) Obi; 5) Baraba; 6) Aralsk; 7) Amur; 8) Ussuri; 9) South-Western; 10) Nikolayevsk; 11) Sakhalin; 12) Okhotsk; 13) Western Kamchatka; 14) Eastern Kamchatka; 15) Anadyr; 16) Chukotsk; 17) Commodore Island.

Principal causes for slow progress and undevelopment of the Russian fisheries in Siberia (climate, lack of railways, lack of ships, routine methods, rapaciousness, poor policy of the old Russian Government; lack of capital and initiative, low state of culture of the native population, etc.). Rôle played by Japan in the fisheries of Eastern Siberia. The future of Siberian fisheries. Siberian fish as a product for the world's markets.

Alexander G. Ruthven.

Geography in Museums of Zoology.

Museums of Zoology are neglecting to gather the data needed in the study of zoögeographical problems. This is unfortunate for the accumulation of geographic data must be left largely to Museums, and the conditions in nature are being changed rapidly. It is believed that geography should be emphasized, at least to the extent of giving first attention to the securing of data on habits, habitat distribution, and exact range, and that it would be within the scope of legitimate museum activities to provide facilities for investigations in experimental animal ecology.

Carl O. Sauer.

Geography as Regional Economics.

There have been numerous discussions of the scope of geography, and especially there have been examinations of the periphery of the science. Much less attention has been given to the determination of particular objectives within the field of geography. Geography is suffering from a scattering of interests over too broad a field for the limited number of workers engaged in it.

The focussing of attention on certain phases of the field alone appears to give hope of establishing the science solidly. This involves consideration of the content, aims, and methods of such a specific type of inquiry. In this country historical geography has been treated in such a manner.

A voluntary limitation of research by a group of workers to the field of regional economic geography is probably the most urgent need of the science to-day. Regional economics has not been preempted by economic science and belongs most appropriately to geography. The essential problems are 1) the determination of bases of unity of the area, 2) the inquiry into advantages and handicaps inherent in the area, 3) the time element as affecting stage of development, and 4) the analysis of the entire economic complex of the region. It follows that any area, geographically defined, is an appropriate subject of inquiry, and that the inquiry must not be limited to the evaluation of so-called geographic factors.

In the method of research, work needs to be done in forming a scientific discipline for 1) agrogeographic research, as referring to rural conditions, especially the utilization of the land, 2) urban studies, and 3) movement of trade.

A logical as well as pragmatic sanction is at hand for such studies, and by means of them geography may knock successfully at the door of the business world and, as well, it may present itself as an advisor to governmental policy.

Problems of Land Classification—Printed in full herewith.

J. J. Sederholm (Introduced by Lawrence Martin).

Finland as an Independent Republic—Read by Title.

The Grand Duchy of Finland before the world war, its boundaries, topography, geology, hydrography, meteorology, vegetation and fauna; population, industry, commerce, administration, history and culture.

Finland during the world war and its own civil war.

The present Republic of Finland, its boundaries, constitution, politics and economy; relations to neighboring states (a land question, etc.), and to the community of mankind; aspirations for the future.

An Expedition to Urïan Haï—Read by Title.

Situation and history of Urïan Haï. Earlier expeditions. Organization of the author's expedition. Through revolutionary Russia to Minussinsk and over the Saïan Mountains to Bïelotsarsk. Work of the expedition. The southern source tributary of Yenisseï. Tannu Ola mountains. Return along the Yenisseï River on a raft. Through Siberia and Russia at the eve of the Bolshevik revolution.

Soïotes, Mongols and Russian colonists, their languages, customs and inter-relations. Natural resources and future of the country.

Ellen Churchill Semple.

The Grain Trade of Acient Athens—Printed in full herewith.

V. E. Shelford.

Experimental Animal Climatology.

Methods of simulating climatic conditions in the laboratory were illustrated. The effects of climatic factors, temperature, moisture, light, rainfall, barometric pressure, air movement, etc., upon growth, fecundity, and general success or failure of various noxious and useful animals as shown by experiment were discussed. Methods of checking experimental results with field observations, with crop-pest and human death rate statistics, etc., were brought out. The importance of experimentation (a) in determining the kind of weather and climatic records to be made, (b) in the prediction of the rise of insect pests and controlling their numbers, etc., (c) in eliminating errors in conclusions as to factors responsible for various geographic phenomena were stressed.

Forrest Shreve.

Vertical Gradients of Evaporation and Soil Moisture in Desert and Coastal Mountains.

The larger features of plant distribution in arid and semi-arid regions are determined by moisture conditions rather than by conditions of temperature. The rate of evaporation is a measure of the conditions tending to cause the loss of water by plants. The percentage of soil moisture is a measure of the water supply for plants. The ratio of the latter to the former gives a concrete expression of the moisture conditions for plants, and is more significant than the ratio of precipitation to evaporation. The gradients of evaporation and soil moisture have been determined through 5,000 ft. of altitude in the Santa Catalina mountains in southern Arizona, and in the Santa Lucia mountains on the coast of central California. The paper described the contrasting conditions of the two mountains.

Guy C. Smith (By Invitation of Council).

Geographic Influences in Marketing—Illustrated by the Meat Industry.

This paper endeavored to show how geographic conditions have exerted an influence upon our machinery of distribution. First: As related to the problem of middlemen in general, and second: as related to one industry in particular.

The functions of middlemen are rather highly specialized. One of the chief of these functions is that of assembling the products, which becomes necessary for the following reasons:

1. The commodities are produced by small and widely separated producers.
2. They vary so widely in grade and quality that without assembling, it would be impossible to secure the various grades in commercial quantities.
3. They must be transferred to the principal markets where there is a demand for them.
4. They must be assembled for storage because of their seasonal production.

Geographic factors have also been influential in determining where middlemen shall be located, both for the assembling of products locally and in primary markets.

The points at which the grading of products is carried on, as well as the location of storage facilities, are also the result in part of geographic conditions. Seasonal production and storage are closely related to the whole system of buying and selling for future delivery.

The location of live stock markets has been determined by the location of live-stock producing areas of the West in relation to the large consuming population of the East. The average thousand pound steer produces dressed beef weighing about five hundred and fifty pounds. It is more economical to ship dressed beef than it is the live animal.

The seasonal production of lambs makes centralized live stock markets and slaughtering establishments necessary since the source of supply moves from California beginning in April to Virginia, Ontario and the range states in August, and the Middle Western states during the winter and early spring. Small packing plants located in these various sections of production would be very busy for a few weeks and comparatively idle the rest of the year.

Differences in the density of population in different parts of the country have made necessary different methods of distributing the finished products. In the large cities and the thickly populated area of the East, branch houses are the most effective method, while in the more sparsely settled sections of the West the car route method of distribution has been developed.

Refrigeration has been a very important factor in the meat industry in order to overcome the difficulties of distance and temperature.

The supply and the prices of meat products are effectively influenced by the seasons and even by weather conditions.

Eugene Van Cleef.

Rainfall Maps of Latin America, Excepting the West Indies.

Manuscript maps prepared for the Latin-American Division of the "Inquiry" were presented for comment and criticism.

The World's Markets—A Map Based on Natural Regions.

A map for business men in manuscript form, based on the several classifications of Natural Regions, but modified to meet trade needs was presented for criticism.

Stephen S. Visher.

Some Aspects of the Geography of South Dakota—Read by Title.

The boundaries of Dakota were in large part located in respect to streams: the eastern boundary is mostly along the Sioux and the Red rivers; the western boundary is the meridian passing through the mouth of the Yellowstone River; the southern boundary is partly made by the great western bend of the Missouri and is partly along the divide between the White and Niobrara rivers. The northern boundary of South Dakota is approximately halfway between the southern boundary and Canada.

The fact that South Dakota is mostly in the Great Plains where the rainfall is often insufficient for agriculture, and where the rivers are too small for extensive navigation, caused its settlement to be delayed until the land to the east was practically all settled, and until railways furnished an outlet for farm produce. The population of Dakota was only a few thousand until 1875. During the wet years of the early 1880's there was much railway construction and a great influx of settlers, and the population increased to more than 400,000 in 1887, or about two thirds of the present figure. The severe droughts of the late 1880's and the 1890's reduced the population greatly, but it was increased again by good times—wet years—in the 1900's. However drought followed in 1910-12 and the states population in 1915 was less than in 1910.

The character of the native fauna and flora has had important influences. The bison was the chief food of the Indians and the fur trade was the most important source of wealth before 1875, and it has been by no means unimportant since then. The nutritive native grasses, which are cured to natural hay by the dry autumns and which retain their food value throughout the dry winters, are still one of the chief assets of the area. Because of them, grazing is successful even in winter, except when interfered with by the occasional droughts and blizzards. Another resource which has aided stock-raising and settlement in general is the availability of artesian waters. Flowing wells have been obtained at slight expense in much of the state.

The geography of South Dakota is discussed comprehensively in Bull. 8 of the S. D. Geological Survey, Vermilion. S. D., 1918.

R. H. Whitbeck.

Geography and Man in Cuba.

The four hundred years of Cuban history illustrate well the dominant influence of two geographical facts, (1) the insularity of Cuba and (2) its geographical position. It was this geographical position in the belt of the Trades which led to its discovery and colonization by the Spanish whose sailing vessels crossed the ocean in the belt of Trades. The Spanish made no settlements in the belt of the Westerlies, excepting as they penetrated those belts from the region of the Trade Winds. The fact that Cuba remained a Spanish possession long after the colonies on the American continent obtained their independence is the result of its insularity. When one of the colonies on the continent had secured its independence, it gave assistance to others, and thus these colonies successfully threw off Spanish rule. Cuba tried it repeatedly, but none of the former Spanish colonies in America had sufficient sea power to go to the aid of Cuba. It was only when a sea power like the United States came to her assistance that her independence was gained.

Furthermore, Cuba's insularity probably saved the island from being actually a part of the United States. Had the narrow Florida strait not separated Cuba from Florida we doubtless would have taken Cuba when we purchased Florida from Spain. On the other hand, the nearness of Cuba to our own doors was the main reason for our going to her aid in her final struggle for independence. We took little interest in the revolutions in the Philippines until we declared war against Spain on account of Cuba.

The advantage of the geographical position which Cuba possesses comes out again in the great prosperity of the sugar industry. Nowhere else is the cane sugar industry so prosperous or growing so healthily. The reason again is because Cuba lies near the United States, the greatest sugar market in the world and a country with capital for foreign investment. Had Cuba been in the East Indies or off the coast of Africa it would have had no such economic development as it has undergone in recent years. The foreign trade of Cuba is now the largest per capita in the world. The exports of sugar alone reached over $300 per capita in 1920 and foreign trade is more than $400 per capita. Half of the capital invested in the two hundred centrals and their surrounding plantations is American.

Geography and Man at Panama—Read by Title.

The building of the Panama Canal illustrates the interaction of three factors which always operate in human geography. First, the part played by geographical conditions; that is, the earth factor. Second, the part played by man; that is, the human factor. Third, the influence of the particular period of history in which the event took place, that is, the time factor.

Geographical conditions determined the most suitable place for building the Panama Canal, yet the Colombians would probably never have built the canal. The geographical factor was favorable, but the human factor was lacking. The French attempted a canal at Panama at a time when knowledge of sanitation and the perfecting of excavating and other machinery had not reached a stage adequate to so great an undertaking, and the French effort failed. Americans did not undertake the canal until they had reached a certain stage in their own national development and had come to feel the imperative need of the canal and to be sure of their financial and engineering ability to complete it. Our geographical position made it strategically imperative that we, and not any other power, should build and control the canal. Therefore, the construction of the canal between 1904 and 1914 was due to the conjunction of three factors, (1) a favorable site for the canal, (2) a nation that was competent to do the job, and (3) the favorable time for undertaking it.

The canal has cost about 460 million dollars for construction, fortification and operation. About 2,500 ships are now traversing the canal annually and the tolls pay the actual cost of operation but nothing more. The slides still occur but are not as a rule serious. Twenty thousand people are still employed by the Government in the Canal Zone, about seventeen thousand of these being negroes. The Government is doing everything possible to make the canal route attractive and to provide at the canal every facility which passing ships may require.

The people live under a form of paternalistic state socialism, the Government being practically the only property owner and employer in the Zone.

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Figure 11

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To accompany The Maumee-Wabash Waterway. Charles R. Dryer
Annals of the Association of American Geographers, Vol. IX, pp. 41-51

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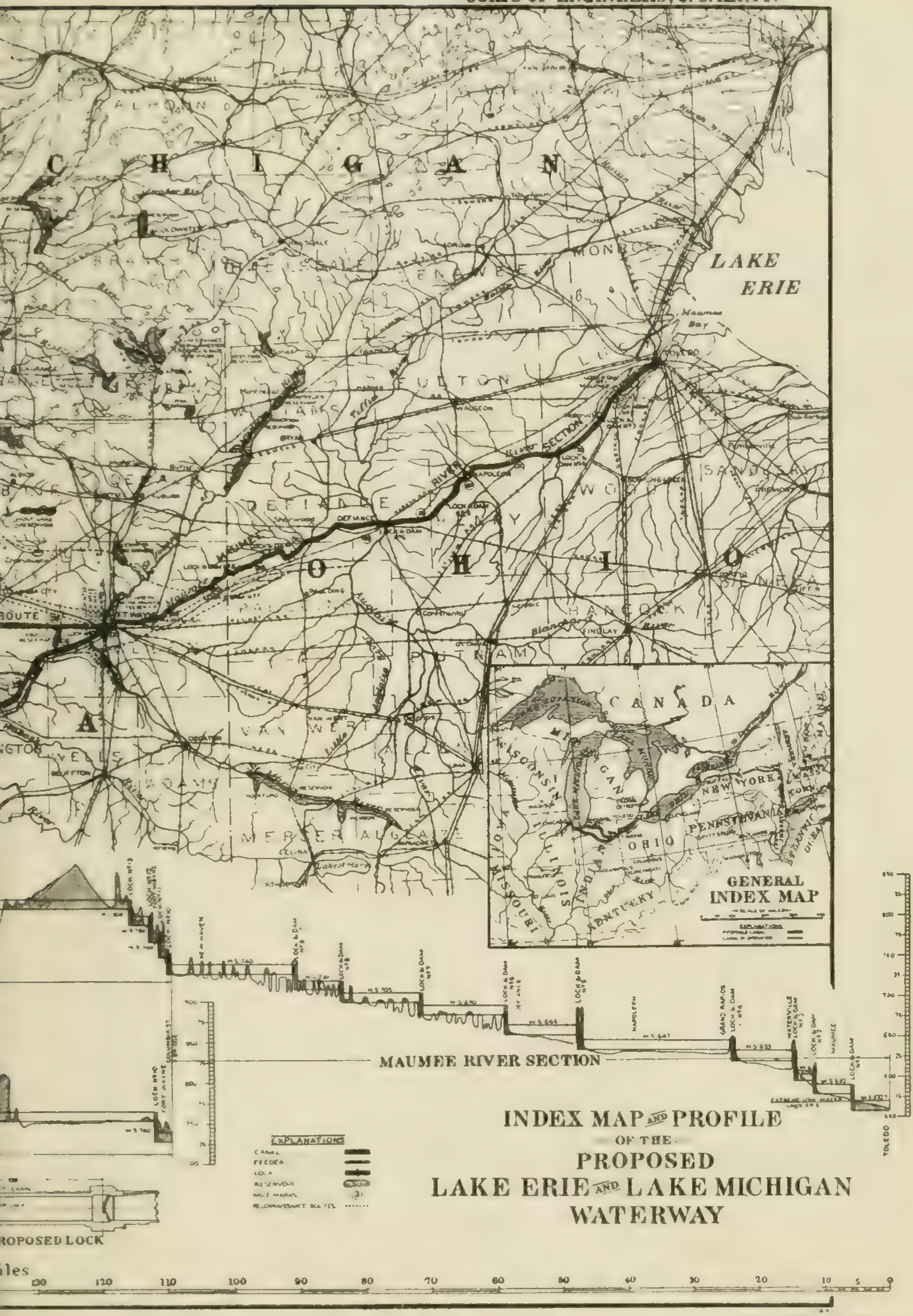
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TOLEDO
OHIO
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WILLIAMS
DEFIANCE
HENRY
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SANDUSKY
SENECA
HANCOCK
PUTNAM
VAN WERT
ALLEN
MERCER
AUGLAIZE
PAULDING
MONROE
LENAWEE
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INDEX MAP AND PROFILE
OF THE
PROPOSED
LAKE ERIE AND LAKE MICHIGAN
WATERWAY
130 120 110 100 90 80 70 60 50 40 30 20 10 5 0

Figure 3

The Wabash Trough. New Harmony Sheet

To accompany The Maumee-Wabash Waterway. Charles R. Dryer
Annals of the Association of American Geographers, Vol. IX, pp. 41-51


DOGTOWN HILLS
KIPPLECHAW
ILLINOIS
INDIANA
LOUDONS ISLAND
LITTLE WABASH R
WHITE CO
GALLETIN CO
NEW HAVEN
MT VERNON
OHIO R
DIAMOND ISLAND
SLIM ISLAND
CYPRESS BAYOU
LAKE
WABASH ISLAND
OHIO
SHAWNE TOWN HILLS


PRINCETON
MC CLEARYS BLUFF
EDWARDS CO.
WHITE CO.
FOOTS POND HILLS
SINKHOLE
GIBSON CO.
POSEY CO.
BLACK R.
L. FOX R.
FOX R.
FOX ISLAND
NEW HARMONY
ILLINOIS
INDIANA
RIBEYRE ISLAND
ILLINOIS

Figure 4

The Wabash Trough. Vincennes Sheet

To accompany The Maumee-Wabash Waterway. Charles R. Dryer
Annals of the Association of American Geographers, Vol. IX, pp. 41-51

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Annals

8-11(1918-21)

Mt CARMEL
HANGING ROCK
CYPRESS SWAMP
WHITE R.
GORDON HILLS
CLAYPOLE HILLS
PATOKA R.
PATOKA
GIBSON CO.
KNOX CO.
CATFISH BEND
St FRANCISVILLE
DICKSBURG HILLS
DESCHEE
SAND MOUND
CHIMNEY HILLS
HAZLETON
DECKER
SAND DUNES


SULLIVAN Co
CRAWFORD Co.
LAWRENCE Co
BUSSERON CR
ROSSELLVILLE
GRAVEL MOUNDS
SAND DUNES
AND SWALES
MORAINE
GRAVEL PIT
LAWRENCEVILLE
HILL
HILL
VINCENNES
HILLS
D DUNES

Figure 5

The Wabash Trough. Terre Haute Sheet

To accompany The Maumee-Wabash Waterway. Charles R. Dryer
Annals of the Association of American Geographers, Vol. IX, pp. 41-51

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VERMILLION Co.
PARKE Co.
VIGO Co.
SAND DUNES
COAL CR.
MORAINE
SAND DUNES
WEST TERRE HAUTE
TERRE HAUTE
SUGAR CR.
SAND DUNES
HONEY CR.
VIGO Co.


CLARK CO.
CRAWFORD CO.
DUNES
SAND DUNES
DUNES
PALESTINE
SAND DUNES
SULLIVAN CO.
KNOX CO.

Figure 6

The Wabash Trough. Clinton Sheet

To accompany The Maumee-Wabash Waterway. Charles R. Dryer

Annals of the Association of American Geographers, Vol. IX, pp. 41-51

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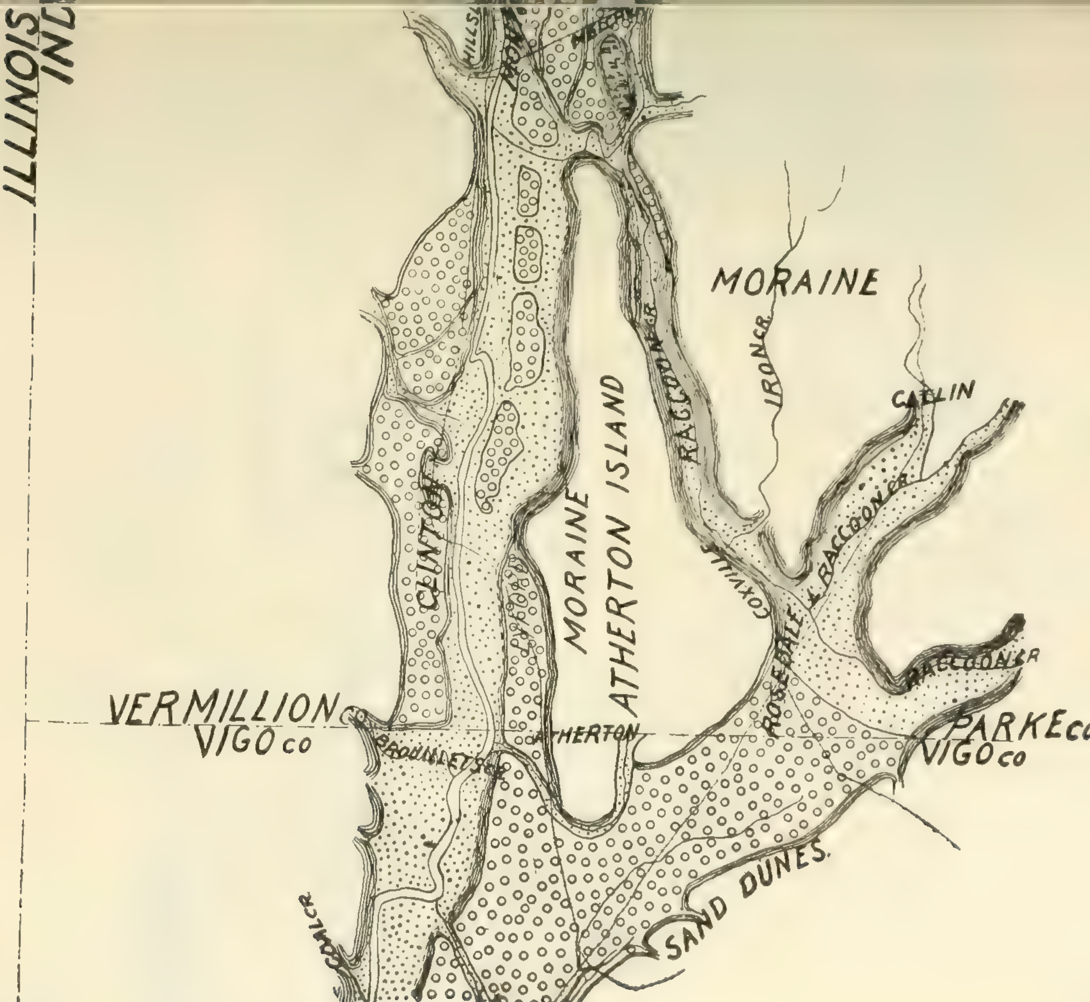
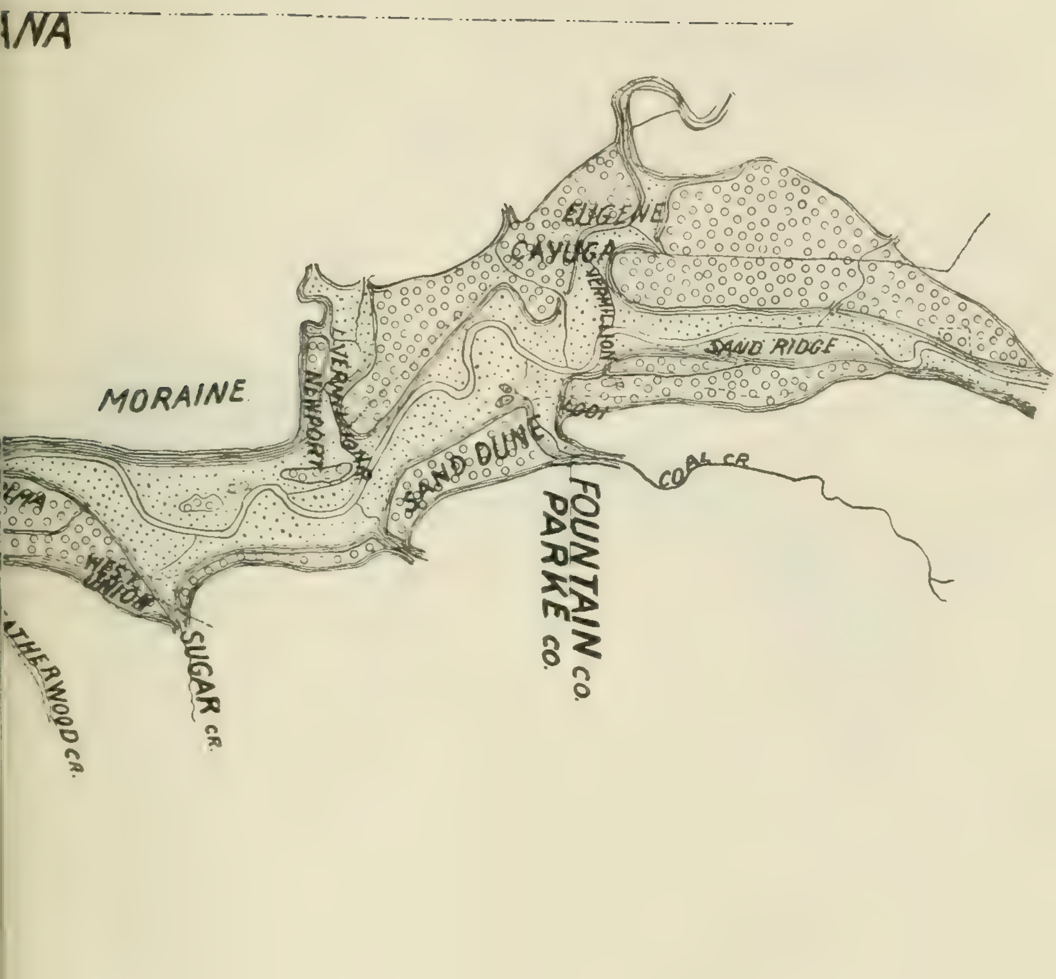
9-10 (1919-20)


ILLINOIS
IND
VERMILLION CO
VIGO CO
CLINTON
MORAINE
ATHERTON ISLAND
ATHERTON
MORAINE
RACCOON CR
IRON CR
CATLIN
COXVILLE
ROSEDALE
L. RACCOON CR
RACCOON CR
PARKE CO.
VIGO CO
SAND DUNES.
COAL CR

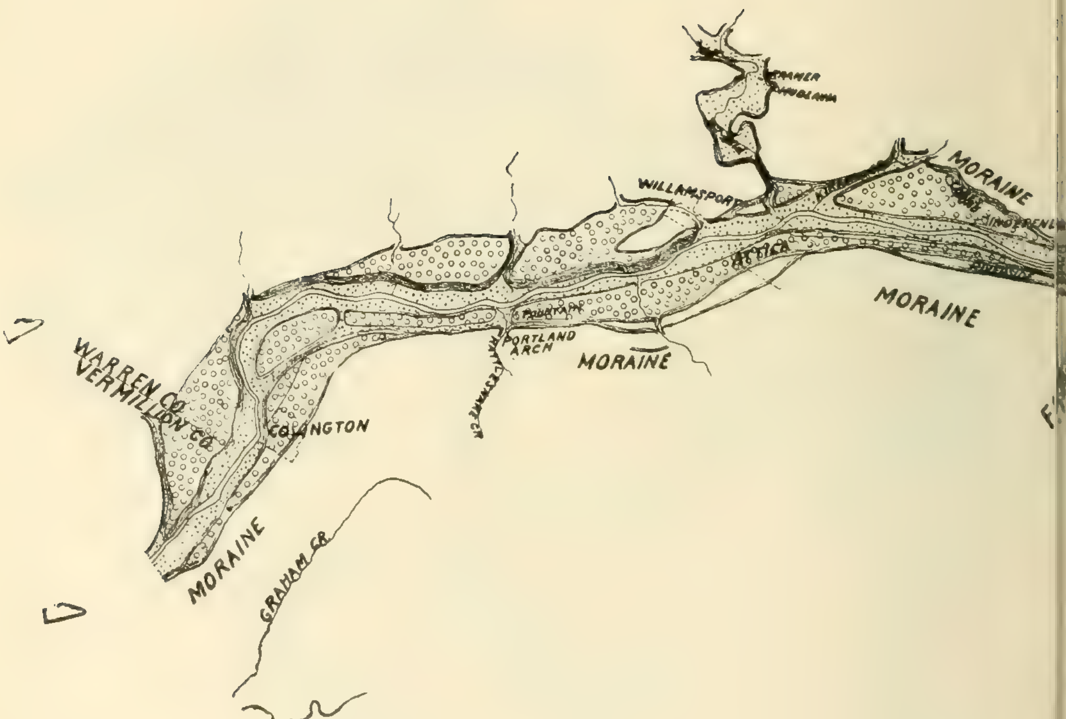


ANA
MORAINE
EUGENE
CAYUGA
SAND RIDGE
NEWPORT
SAND DUNE
WEST UNION
SUGAR CR.
COAL CR
FOUNTAIN CO.
PARKE CO.

Figure 7

The Wabash Trough. Lafayette Sheet

To accompany The Maumee-Wabash Waterway. Charles R. Dryer
Annals of the Association of American Geographers, Vol. IX, pp. 41-51



WILLAMSPORT
MORAINE
ATTICA
MORAINE
PORTLAND
ARCH
MORAINE
WARREN CO.
VERMILLION CO.
MORAINE
GRAHAM CR.

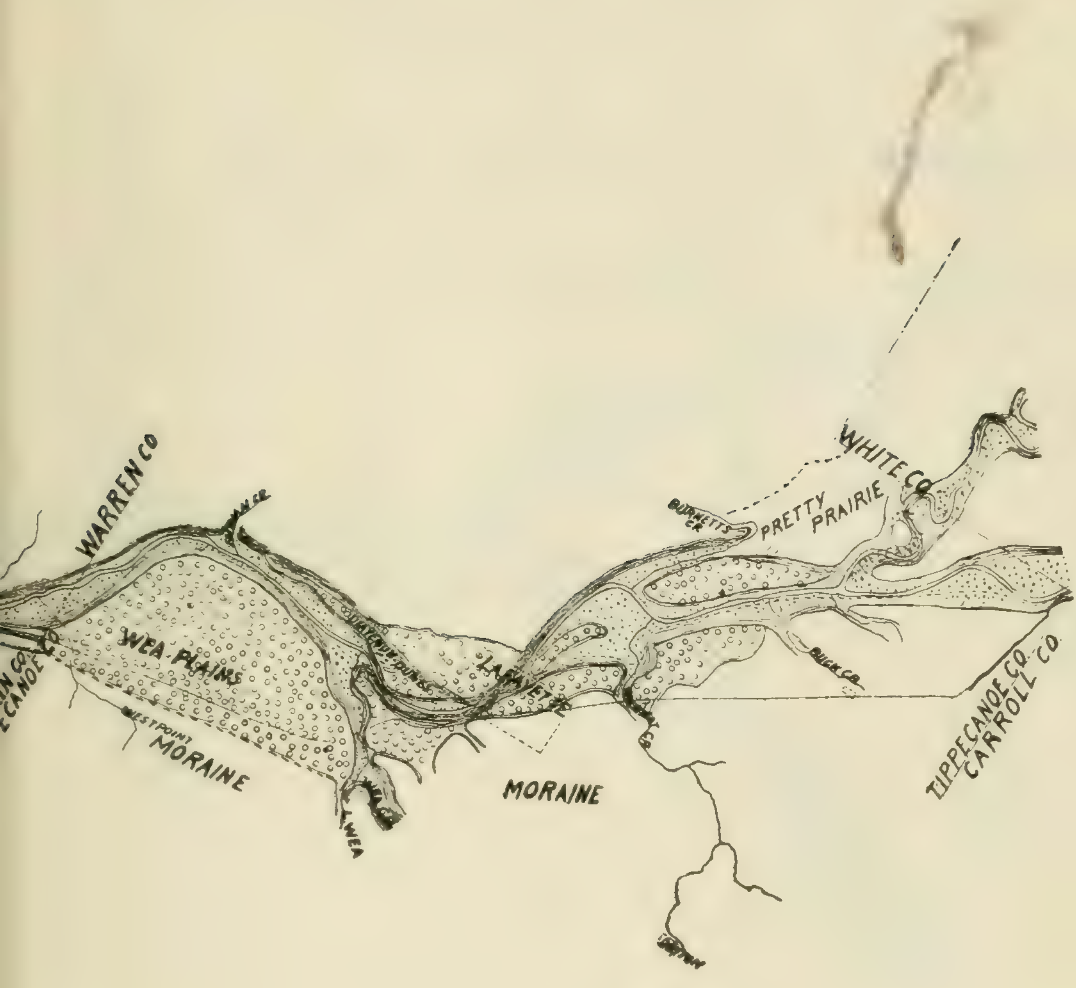
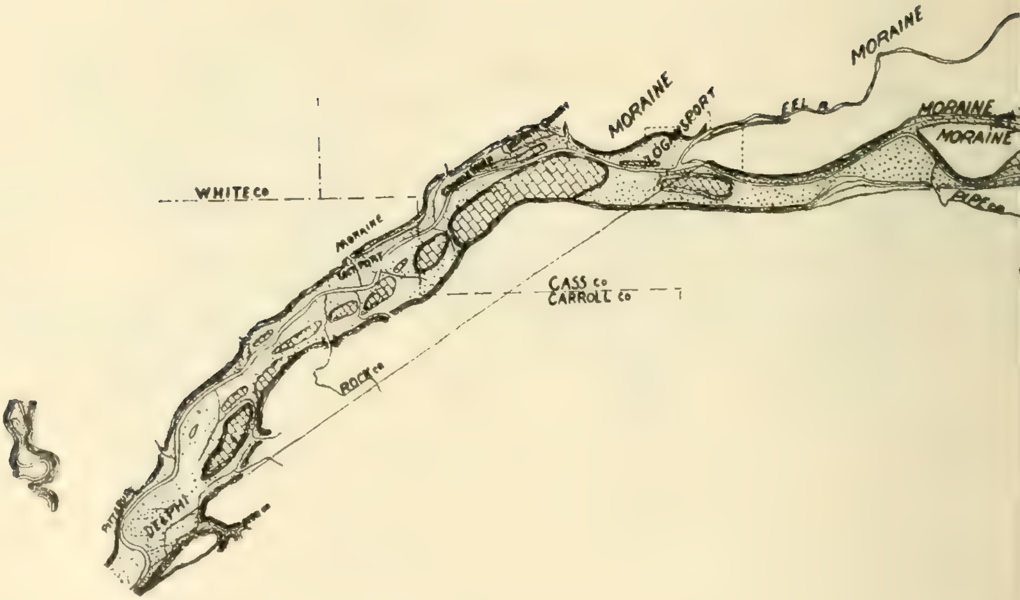

WARREN CO
WHITE CO
PRETTY PRAIRIE
BURNETTS CR
WEA PLAINS
LAFAYETTE
MORAINE
WESTPOINT
MORAINE
WEA
BUCK CR
TIPPECANOE CO
CARROLL CO

Figure 8

The Wabash Trough. Logansport Sheet

To accompany The Maumee-Wabash Waterway. Charles R. Dryer
Annals of the Association of American Geographers, Vol. IX, pp. 41-51


MORAINE
MORAINE
MORAINE
MORAINE
MORAINE
EEL R.
LOGANSPORT
WHITE CO
CASS CO
CARROLL CO
ROCK CO

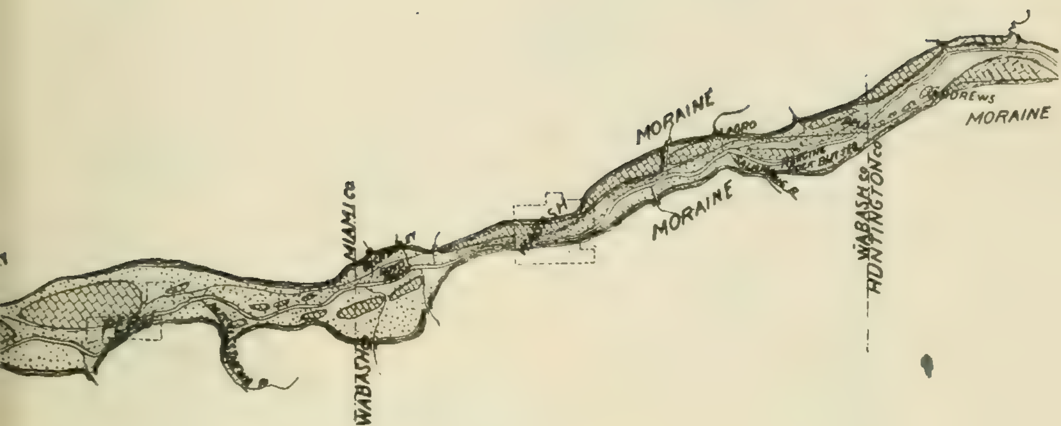
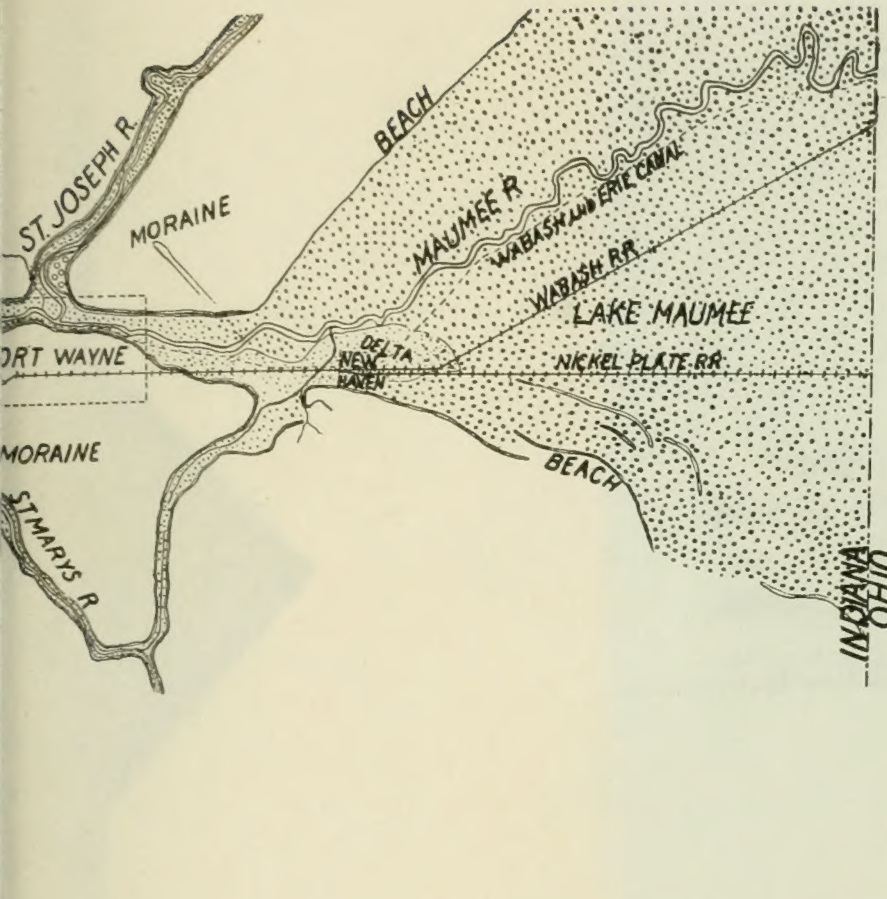

MORAINE
MORAINE
MORAINE
MIAMI Co
WABASH
WABASH Co
HUNTINGTON Co

Figure 9

The Wabash Trough. Fort Wayne Sheet

To accompany The Maumee-Wabash Waterway. Charles R. Dryer
Annals of the Association of American Geographers, Vol. IX, pp. 41-51


ABOITE R.
MORAINE
WHITLEY CO
MORAINE
ROANOKE
HUNTINGTON CO
ALLEN CO
HUNTINGTON
LITTLE WABASH R.
WABASH R.


ST. JOSEPH R.
MORAINE
BEACH
MAUMEE R
WABASH AND ERIE CANAL
WABASH RR
LAKE MAUMEE
DELTA
NEW HAVEN
NICKEL PLATE RR
ORT WAYNE
MORAINE
BEACH
ST MARYS R
INDIANA
OHIO